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# REPORT TO THE CONGRESS ON THE STRATEGIC DEFENSE INITIATIVE

APRIL 1987



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## LIST OF ACRONYMS

ABM	Antiballistic Missile
ACS	Attitude Control System
ADOP	Advanced Distributed Onboard Processor
AFATL	Air Force Armament Lab
AFSC	Air Force Systems Command
AOA	Airborne Optical Adjunct
AOS	Airborne Optical Sensor
ARC	Advanced Research Center
ASAT	Antisatellite
ATBM	Antitactical Ballistic Missile
ATM	Antitactical Missile
ATP	Acquisition, Tracking, and Pointing
ATP-FC	Acquisition, Tracking, Pointing, and Fire Control
BM	Battle Management
BM/C <sup>3</sup>	Battle Management/Command, Control, and Communications
BMD	Ballistic Missile Defense
BMDPM	Ballistic Missile Defense Program Manager
BSTS	Boost Surveillance and Tracking System
C <sup>2</sup>	Command and Control
C <sup>3</sup>	Command, Control, and Communications
CADE	Combined Allied Defense Experiment
CDI	Conventional Defense Initiative
CER	Cost-Estimating Relationship
CHECKMATE	Compact High Energy Capacitator Modular Advance Technology Experiment
CICA	Competition in Contracting Act
CNA	Center for Naval Analysis
CONUS	Continental United States
CRS	Congressional Research Service
CW	Continuous Wave
CY	Calendar Year
DARPA	Defense Advanced Research Projects Agency

DCDS	Distributed Computer Design System
DBMS	Data Base Management System
DEW	Directed Energy Weapons
DF	Deuterium Floride
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOE	Department of Energy
DRB	Defense Resources Board
DSDIO	Director, Strategic Defense Initiative Organization
DSP	Defense Support Program
DST	Defense Suppression Threat
DTS	Defensive Technology Study
ECM	Electronic Countermeasure
EML	Electromagnetic Launcher
EMP	Electromagnetic Pulse
ERINT	Extended Range Interceptor
ERIS	Exoatmospheric Reentry Vehicle Interception System
ESD	Electronic Systems Division
EV	Experimental Version
EXCOM	Executive Committee
FCRC	Federal Contract Research Center
FEL	Free Electron Laser
FLAGE	Flexible Lightweight Agile-Guided Experiment
FS <sup>3</sup>	Future Strategic Strategy Study
FTV	Functional Technical Validation
FY	Fiscal Year
GAO	General Accounting Office
GBHRG	Ground-Based Hypervelocity Rail Gun
GBL	Ground-Based Laser
GBMI	Ground-Based Midcourse Interceptor
HEDI	High Endoatmospheric Defense Interceptor
HEDS	High Endoatmospheric Defense System
HELSTF	High Energy Laser Systems Test Facility
HIBREL	High Brightness Relay

HOE	Homing Overlay Experiment
HVG	Hypervelocity Gun
HVL	Hypervelocity Launcher
IBSS	IR Background Signature Survey
ICBM	Intercontinental Ballistic Missile
IEG	Independent Evaluation Group
IMU	Inertial Measurement Unit
IR	Infrared
IRBM	Intermediate-Range Ballistic Missile
ISAT	Invite, Show, and Test
IST	Innovative Science and Technology
ISWG	Integrated Support Working Group
ITD	Integration Test and Demonstration
JPO	Joint Program Office
KEW	Kinetic Energy Weapons
KJ	Kilojoules
KKV	Kinetic-Kill Vehicle
KMR	Kwajalein Missile Range
L&TH	Lethality and Target Hardening
LADAR	Laser Radar
LAMP	Large Advanced Mirror Program
LEAP	Lightweight Exoatmospheric Advanced Projectiles
LODE	Large Optics Demonstration Experiment
LODTM	Large Optics Diamond Turning Machine
LRINF	Longer-Range Intermediate Nuclear Forces
LSA	Logistics Support Analysis
LTH	Lethality and Target Hardening
LWIR	Long Wavelength Infrared
MaRV	Maneuvering Reentry Vehicle
MeV	Million Electron Volts
MIRACL	Mid-Infrared Advanced Chemical Laser
MIRV	Multiple Independently Targeted Reentry Vehicle
MOU	Memorandum of Understanding
MKV	Miniature Kill Vehicle
MMW	Multimegawatt
M&S	Materials and Structures

MT	Metric Ton
MTS	Member of the Technical Staff
NASA	National Aeronautics and Space Administration
NCA	National Command Authority
NCC	Noncancelable Commitment
NDEW	Nuclear Directed Energy Weapon
NN	Nonnuclear
NPB	Neutral Particle Beam
NSWC	Naval Surface Weapons Center
NTB	National Test Bed
NTF	National Test Facility
NTM	National Technical Means
OASD/ISP	Office of the Assistant Secretary of Defense for International Security Policy
OJCS	Office of the Joint Chiefs of Staff
PBV	Post-Boost Vehicle
PCM	Pyrotechnic Countermeasure
PDL	Process Description Language
PPBS	Planning, Programming, and Budgeting System
R&D	Research and Development
RF	Radio Frequency
RFL	Radio-Frequency Linac
RFP	Request for Proposal
RDT&E	Research, Development, Test, and Evaluation
RV	Reentry Vehicle
SA/BM	Systems Analysis and Battle Management
SAL	Strategic Arms Limitation
SALT	Strategic Arms Limitation Talks
SATKA	Surveillance, Acquisition, Tracking, and Kill Assessment
SBHRG	Space-Based Hypervelocity Rail Gun
SBI	Spaced-Based Interceptor
SBIR	Small Business Innovative Research
SBKKV	Space-Based Kinetic-Kill Vehicle
SBL	Space-Based Laser
SBNPB	Space-Based Neutral Particle Beam

SBPB	Space-Based Particle Beam
SDC	Strategic Defense Command
SDI	Strategic Defense Initiative
SDIAC	Strategic Defense Initiative Advisory Council
SDII	Strategic Defense Initiative Institute
SDIO	Strategic Defense Initiative Organization
SEMP	Systems Engineering Management Plan
SE/SI	Systems Engineering/Systems Integration
SETA	Systems Engineering and Technical Assistance
SGEMP	System-Generated Electromagnetic Pulse
SLBM	Submarine-Launched Ballistic Missile
SNIFE	SDI Network Interface Processor Engine
Sol-Gel	Solution-Gelatin
SLKT	Survivability, Lethality, and Key Technologies
SPADATS	Space Detection and Tracking System
SSTS	Space Surveillance and Tracking System
STA	Science and Technology Agent
STM	Significant Technical Milestone
TBM	Tactical Ballistic Missile
TIR	Terminal Imaging Radar
TVE	Technology Validation Experiment
TW/AA	Tactical Warning/Attack Assessment
USDRE	Under Secretary of Defense for Research and Engineering
UV	Ultraviolet
VHSIC	Very High-Speed Integrated Circuits
WSMR	White Sands Missile Range

## GLOSSARY

Acquisition - The process of searching for and detecting a potentially threatening object in space. An acquisition sensor is designed to search a large area of space and to distinguish potential targets from other objects against the background of space.

Algorithms - Rules and procedures for solving a problem.

Antiballistic Missile System - A missile system designed to intercept and destroy a strategic offensive ballistic missile or its reentry vehicles.

Antisatellite Weapon - A weapon designed to destroy satellites in space. The weapon may be launched from the ground or an aircraft or be based in space. The target may be destroyed by a nuclear or conventional explosion, by collision at high speed, or by a directed energy beam.

Architecture - Description of all functional activities to be performed to achieve the desired level of defense, the system elements needed to perform the functions, and the allocation of performance levels among those system elements.

Ballistic Missile - A pilotless vehicle propelled into space by rocket engines. Thrust is terminated at a predesignated time after which the missile's reentry vehicles are released and follow free-falling trajectories toward their ground targets under the influence of gravity. Much of a reentry vehicle's trajectory will be above the atmosphere.

Battle Management - Includes assets to perform the computations to direct target selection and fire control, perform kill assessments, provide command and control, facilitate communication, and assist a variety of military users in the accurate determination of their positions.

Boost Phase - The first phase of a ballistic missile trajectory during which it is being powered by its engines. During this phase, which usually lasts 3 to 5 minutes for an ICBM, the missile reaches an altitude of about 200 km whereupon powered flight ends and the missile begins to dispense its reentry vehicles. The other phases of missile flight, including midcourse and reentry, take up the remainder of an ICBM's flight time of 25 to 30 minutes.

Booster - The rocket that "boosts" the payload to accelerate it from the earth's surface into a ballistic trajectory, during which no additional force is applied to the payload.

Brightness - As used in the SDI, brightness is the measure of source intensity. To determine the amount of energy per unit area on a target, both source brightness and source-target separation distance must be specified.

Bus - The warheads on a single missile are carried on a platform or "bus" (also referred to as a post-boost vehicle).

Chaff - Strips of frequency-cut metal foil, wire, or metallized glass fiber used to reflect electromagnetic energy, usually dropped from an aircraft or expelled from shells or rockets as a radar countermeasure.

Chemical Laser - A laser in which a chemical action is used to produce pulses of intense light.

Communication - Communication between two or more ground sites, between satellites, or between a satellite and a ground site.

Decoy - A device constructed to look and behave like a nuclear-weapon-carrying warhead which is far less costly, much less massive, and can be deployed in large numbers to complicate defenses.

Directed Energy - Energy in the form of atomic particles, pellets, or focused electromagnetic beams that can be sent long distances at, or nearly at, the speed of light.

Directed Energy Weapon - A weapon that employs a tightly focused and precisely directed beam of very intense energy, either in the form of light (a laser) or in the form of atomic particles traveling at velocities at or close to the speed of light (a particle beam weapon). (See also Laser and Particle Beam Weapon.)

Discrimination - The process of observing a set of attacking objects and determining which are decoys or other non-threatening objects.

Electromagnetic Gun - A gun in which the projectile is accelerated by electromagnetic forces rather than by an explosion as in a conventional gun.

Endoatmospheric - Within the earth's atmosphere, generally considered to be at altitudes below 100 km.

Engagement Time - The amount of time that a weapon platform takes to negate a given target. This includes not only firing at the target but all other necessary weapon functions involved that are unique to that particular target.

Excimer Laser - A laser in which emission is stimulated when a gas is shocked with electrical energy and the excited medium emits light when returning to a ground state.

Exoatmospheric - Outside the earth's atmosphere, generally considered to be at altitudes above 100 km.

Fluence - The amount of energy per unit area on target. (It should be specified whether this is incident or absorbed fluence.)

Gamma Ray - Electromagnetic radiation resulting from nuclear transitions. Although incorrect, high-energy radiation, particularly bremsstrahlung, is sometimes referred to as gamma radiation.

Hardening - Measures which may be employed to render military assets less vulnerable.

Hypervelocity Gun - A gun that can accelerate projectiles to 5 km per second or more; for example, an electromagnetic or rail gun.

Imaging - The process of identifying an object by obtaining a high-quality image of it.

Interception - The act of destroying a target.

Intercontinental Ballistic Missile - A ballistic missile with a range of 3,000 to 8,000 nautical miles. The term ICBM is used only for land-based systems to differentiate them from submarine-launched ballistic missiles, which are also considered strategic, though not necessarily intercontinental.

Intermediate-Range Ballistic Missile - A land-based ballistic missile with a range 2,500 to 3,000 nautical miles. The range is less than that of an ICBM but greater than that of a short- or medium-range ballistic missile. Types of IRBMs currently deployed include the Soviet SS-20.

Kinetic Energy - The energy from the motion of an object.

Kinetic Energy Weapon - A weapon that uses a nonexplosive projectile moving at very high speed to destroy a target on impact. The projectile may include homing sensors and onboard rockets to improve its accuracy, or it may follow a preset trajectory (as with a shell launched from a gun). The projectile may be launched from a rocket, conventional gun, or rail gun.

Laser - (Light Amplification by the Stimulated Emission of Radiation.) A device for producing an intense beam of coherent light. The beam of light is amplified when photons (quanta of light) strike excited atoms or molecules. These atoms or molecules are thereby stimulated to emit new photons (in a cascade or chain reaction) which have the same wavelength and are moving in phase and in the same direction as the original photon. A laser weapon may destroy a target by heating, melting, or vaporizing its surface.

Layered Defense - A defense that consists of several sets of weapons that operate at different phases in the trajectory of a ballistic missile. Thus, there could be a first layer (e.g., boost phase) of defense with remaining targets passed on to succeeding layers (e.g., midcourse, terminal).

Leakage - The percentage of warheads that get through a defensive system intact and operational.

Lethality - Refers to the amount of energy or other beam characteristic required to eliminate the military usefulness of enemy targets by causing serious degradation (mission kill) or destruction (observable kill) of a target system.

Midcourse Phase - That portion of the trajectory of a ballistic missile between the boost phase and the reentry phase. During this phase of the missile trajectory, the missile releases its warheads and decoys and is no longer a single object, but a swarm of RVs, decoys, and debris falling freely along preset trajectories in space.

Multiple Independently Targetable Reentry Vehicle - A package of two or more reentry vehicles which can be carried by a single ballistic missile and guided to separate targets. MIRVed missiles employ a warhead dispensing mechanism called a post-boost vehicle to target and release the warheads.

Neutral Particle Beam - An energetic beam of neutral atoms (no net electric charge). A particle accelerator accelerates the particles to nearly the speed of light.

Nonnuclear Kill - A kill that does not involve a nuclear detonation.

Particle Beam - A stream of atoms or subatomic particles (electrons, protons, or neutrons) accelerated to nearly the speed of light.

Particle Beam Weapon - A weapon that relies on the technology of particle accelerators (atom-smashers) to emit beams of charged or neutral particles which travel near the speed of light. Such a beam could theoretically destroy a target by several means, e.g., electronics upset, electronics damage, softening/melting of materials, sensor damage, and initiation of high explosives. (Stable propagation of particle beams in the atmosphere has never been demonstrated.)

Passive Sensor - A sensor that only detects radiation naturally emitted (infrared radiation) or reflected (sunlight) from a target.

Post-Boost Phase - The portion of a rocket trajectory following the boost phase and preceding the reentry phase.

Post-Boost Vehicle - The portion of a rocket payload that carries the multiple warheads and has maneuvering capability to place each warhead on its final trajectory to a target (also referred to as a "bus").

Rail Gun - A weapon using electromagnetic launching to fire hypervelocity projectiles. Such projectile launchers will have very high muzzle velocities, thereby reducing the lead angle required to shoot down fast objects, lessening windage effects, and flattening trajectories in the atmosphere.

Reentry Vehicle - The part of a ballistic missile that carries the nuclear warhead to its target. The reentry vehicle is designed to reenter the earth's atmosphere in the terminal portion of its trajectory and proceed to its target.

Responsive Threat - A threat which has been upgraded in quality or quantity or with added protective countermeasures in response to a projected capability of defeating (all or part of) the threat.

Signature - The characteristic pattern of the target displayed by detection and identification equipment.

Surveillance - This includes tactical observations, strategic warning, and meteorological assessments, by optical, infrared, radar, and radiometric sensors on space-borne and terrestrial platforms.

Survivability - The capability of a system to avoid or withstand man-made hostile environments without suffering irreversible impairment of its ability to accomplish its designated mission.

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## CHAPTER I INTRODUCTION

### A. PURPOSE OF REPORT

This report describes the Department of Defense's (DoD's) research and technology program efforts needed to meet the goals of the President's Strategic Defense Initiative (SDI). This report responds to Section 1102 of the Department of Defense Authorization Act, Fiscal Year 1985 (Public Law 98-525, October 19, 1984).

### B. SCOPE

This report encompasses activities of the past year and plans for ongoing and future efforts by the DoD to achieve the goals of the SDI. This plan describes the basic program execution by DoD military Services, agencies, and the Strategic Defense Initiative Organization (SDIO). The basic program comprises all SDIO-supported research and technology efforts leading to decisions on whether or not to implement a defensive strategy and develop promising systems for defense against ballistic missiles. This report provides a broad overview of the SDI Program to non-SDI agencies and groups.

### C. PROGRAM GENESIS

In January 1984, the Strategic Defense Initiative was established as a research and technology development program based on the recommendations of the Fletcher Study. In April 1984, the SDIO was formally chartered as a defense agency to manage the DoD's efforts. Specifically, a comprehensive SDI Program was defined to explore key technologies associated with concepts for defense against ballistic missiles. The SDIO was directed to place principal emphasis on technologies using nonnuclear kill concepts. Research on nuclear directed energy weapons is being done to develop an understanding of the potential of this technology and as a hedge against Soviet work in this area.

Specific research efforts are organized in five areas:

- Surveillance, Acquisition, Tracking, and Kill Assessment (SATKA);
- Directed Energy Weapons (DEW) technologies;
- Kinetic Energy Weapons (KEW) technologies;
- Systems Analysis and Battle Management (SA/BM); and
- Survivability, Lethality, and Key Technologies (SLKT).

## CHAPTER II DIRECTOR'S OVERVIEW

### A. INTRODUCTION

The Defense Department's third annual Report to the Congress on the SDI will begin with a review of the SDIO's past accomplishments and introduce the main themes of this year's report. As the Administration requests funding for the fourth and fifth years of the Strategic Defense Initiative and as the 100th Congress considers those requests, it is useful to look ahead at the challenges that remain for this very important Presidential Initiative that continues to be supported by the majority of the American people.

This chapter will emphasize four themes; *see emphasis of*

- The constancy of the SDIO's mission and technical objectives. The essence of the SDIO Program is to explore those technologies that could support an effective defense against ballistic missiles.
- Great progress has been made in some of the technologies that are key to an effective defense against ballistic missiles. Despite large reductions in the SDIO budget, much progress has been made in some key technologies, especially the more mature technologies that could support the initial phase of a phased deployment.
- An evolving investment strategy necessitated by budget reductions. Budget reductions have caused some parts of the Program to slip one to two years, and if continued, will create an imbalance in funding between technology development that forms a base for technology validation and technology validation experiments. In addition, reduced funding has decreased

technical options for strategic defense capabilities in the 1990s.

- A determination to restore program balance and complete the SDIO's mission. The SDIO's budget request for FY 1988 can reduce the technical risk in achieving effective options.

B. THE PRESIDENT'S CHALLENGE

There are three arguments for pursuing a vigorous, goal-oriented SDI Program.

- The U.S. must capitalize upon the very real probability that science and technology can create a safer future in which nuclear missiles become less and less capable of threatening destructive surprise attack.
- The U.S. needs to hedge against the real possibility that Soviet efforts will exploit ballistic missile defense technologies and suddenly breakout, or slowly and surreptitiously creep out, from the Anti-Ballistic Missile (ABM) Treaty.
- The U.S. needs to hedge against possible new Soviet offensive measures that may threaten key elements of our deterrent forces.

Strategic defense against the threat of ballistic missiles would make a strong contribution to U.S. and allied security and freedom.

C. THE SOVIET CHALLENGE IN STRATEGIC FORCES

The President has charged the DoD with defining options for using defense to counter the continuing Soviet progress in improving strategic offensive and defensive forces. Soviet progress, if permitted to continue over the long term without

analogous U.S. advances, will undermine the military balance which is essential to effective and stable deterrence. Soviet continuing progress is evidenced by:

- A wide-ranging effort to improve a ballistic missile force that provides increased prompt, hard-target kill capability--progress that has increasingly threatened the survivability of forces we have deployed to deter Soviet aggression.
- A steadily increasing capability in Soviet active defenses to counter U.S. retaliatory forces and those of our allies, especially if those forces were to be degraded by a Soviet first strike. These defenses include the world's only operational ballistic missile defense, only deployed antisatellite (ASAT) system, and an extensive air defense network.
- An impressive investment in passive defenses aimed at improving the survivability of Soviet forces, military command structure, and national leadership, including rail and road mobility and extensive hardening of various critical installations.
- A steady and expanding research and development program that includes most of the technologies being investigated by the U.S. SDI Program, and which is continually probing the limits of physical phenomena in a search for breakthroughs.
- A continuing military expansion into space as evidenced by the fact that 80% of Soviet space launches have been purely military in nature. This expansion clearly recognizes the high ground of space as a major component of the Soviet drive for military superiority.

- Soviet noncompliance with existing arms control agreements (e.g., construction of the Krasnoyarsk radar), encryption of missile test data, and actions which affect our ability to verify Soviet compliance with possible future agreements (increased deployment of mobile ballistic missiles).

U.S. hopes that the arms limitations process of the 1970s would lead to restraint in creating new strategic offensive capabilities and a reduction in the number of offensive systems have not been realized. Continued Soviet efforts to develop strategic defense capabilities, in conjunction with their extensive offensive nuclear buildup, pose a serious challenge to U.S. and allied security. Therefore, it is in this context that we have dramatically increased our efforts to seek to enhance a stable deterrence with a possible future use of strategic defenses.

#### D. THE TECHNICAL CHALLENGE IN PERSPECTIVE

Achieving effective ballistic missile defenses depends on an ability to attack ballistic missiles in all phases of their trajectories. These phases, shown in Figure II.1, are the boost, post-boost, midcourse, and terminal.

The most important capabilities of an effective defense are associated with:

- Intercepting the ballistic missile in its very vulnerable boost phase. This vulnerability stems from missile design practices that minimize structural weight to maximize payload. Destruction of attacking missiles in this phase can provide defense leverage (i.e., a single defense weapon can destroy a booster, which in turn can eliminate several nuclear warheads and many decoys designed to defeat defenses in the later stages of flight). Equally important,

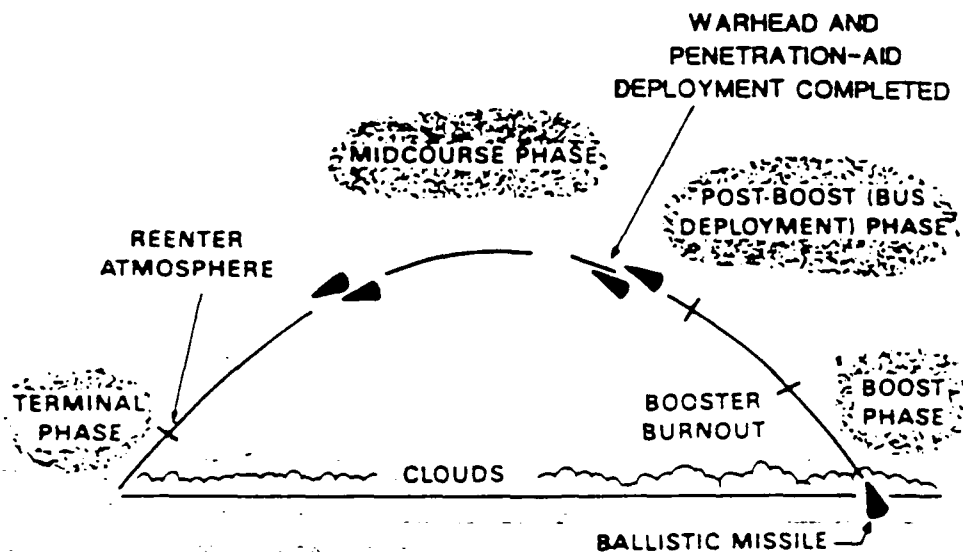


Figure II.1 (U) Phases of a Ballistic Missile Trajectory

destroying even a portion of the attack in the boost phase can completely disrupt tactics designed to overcome defenses in the later phases of ballistic missile flight.

- Intercepting in midcourse flight. The midcourse phase of missile flight is entirely outside the atmosphere and offers the defense the longest period of time (approximately 20-30 minutes) for accomplishing effective ballistic missile intercept. The intercept weapons can be space- or ground-based, and even a limited number of ground sites can provide defense of very large geographic areas. However, a midcourse defense system must provide both early identification (filtering) of nonthreat objects (e.g., decoys, space debris) and continuing attrition of threat reentry

vehicles to minimize the pressure on the terminal defense system. This requires developing effective discriminators as well as missile detectors, and acquisition and tracking systems which can accept information from the boost and post-boost sensors and direct the midcourse interceptors. Failure to start the defense before midcourse could result in a ten- to several hundredfold increase in the number of objects in the threat cloud. The effectiveness of this phase of the defense will be strongly enhanced by the success of the boost and post-boost phases.

- Attacking the ballistic missile several times throughout its flight to the target. This would give defenses a high degree of effectiveness while avoiding the difficult design requirements and potential catastrophic failure modes of a single layer of defense. Attacking such a defense is a complex enterprise requiring large numbers of forces. The major uncertainties in achieving a successful attack and the penalties of failure provide a powerful disincentive for a potential aggressor to attack.

Ballistic missile defense requires sensors to observe the attack, interceptors to destroy the ballistic missiles and warheads, and battle management system elements to efficiently and effectively operate the whole system architecture.

In the 1960s, our studies defined concepts for a layered defense, but we did not then have the technology to achieve the needed capabilities--the technological challenge was simply too great. Later, in the early 1980s, technological progress promised new opportunities, and the President recognized that the U.S. needed to take a comprehensive look at effective defenses. This realization was based on progress in many technologies; among the most important are:

- Small hit-to-kill warheads. These small hit-to-kill projectiles could be launched to high velocities either from a space platform or from the ground with relatively small boosters and could maneuver to hit and destroy the target. Their small size would reduce the cost of their delivery to the target and permit deployment of large numbers, thereby enhancing survivability and providing increased kill probability through multiple intercepts.
- Directed energy weapons. Directed energy weapons could deliver almost instantaneously disruptive energy to the target over thousands of kilometers away. These weapons could be lasers or particle beams capable of large numbers of engagements. The capability of lasers for rapid retargeting and rapid delivery could offset the tight time constraints of boost-phase intercept, where booster burn times are short and missiles are launched simultaneously. In addition to their potential utility as weapons, particle beams could discriminate warheads from decoys by interacting with the objects and inducing characteristic emissions from them.
- Sensors and associated signal and data processing. Sensors, such as infrared and radar systems, could act as the eyes for a large complex set of actions and counteractions. These technologies could provide an unprecedented view of where things are and what they look like. In doing so, they satisfy the demands of acquisition, tracking, identification, discrimination, and decision making for individual weapons.
- Computers and display systems. These include technologies and designs, both for hardware (e.g., the computer and data distribution systems) and software

(e.g., the programs and algorithms), which allow the rapid and accurate receipt, syntheses, analyses, display, and transmission of data necessary to manage and effectively employ the defensive systems. The massive quantities of data which must be processed in extremely short periods, on the order of billionths of a second, require capabilities which exceed those currently available. Major strides in computational capability are needed to increase computing speed by a factor of 10, while simultaneously making the computers smaller and more survivable so that they can be used both on the ground and in space. A key to successfully engaging and destroying thousands and possibly hundreds of thousands of potential targets is the fusion of intelligence data received from a broad array of sensors and the dissemination of this information to weapons systems and battle managers.

Progress in key technologies described above permits the identification of many promising concepts for detection, tracking, identification, intercept, destruction, and damage assessment in all phases of the ballistic missile flight. Figure II.2 depicts defense concepts in relation to the phase of flight against which they would be employed in a strategic defense. The research of the SDIO seeks to determine whether these concepts are feasible and can be effective in a multi-tiered defense. The level of effort required to validate the needed technology is not the same for all concepts. The degree to which they can be brought along to support future defense options requires an investment strategy that depends not only on the maturity of each technology but on the level of resources provided by the Congress.

The SDI Program is not adversely affecting U.S. efforts to provide a technology base for future improved conventional weapons. On the contrary, not only has DoD funding for R&D on

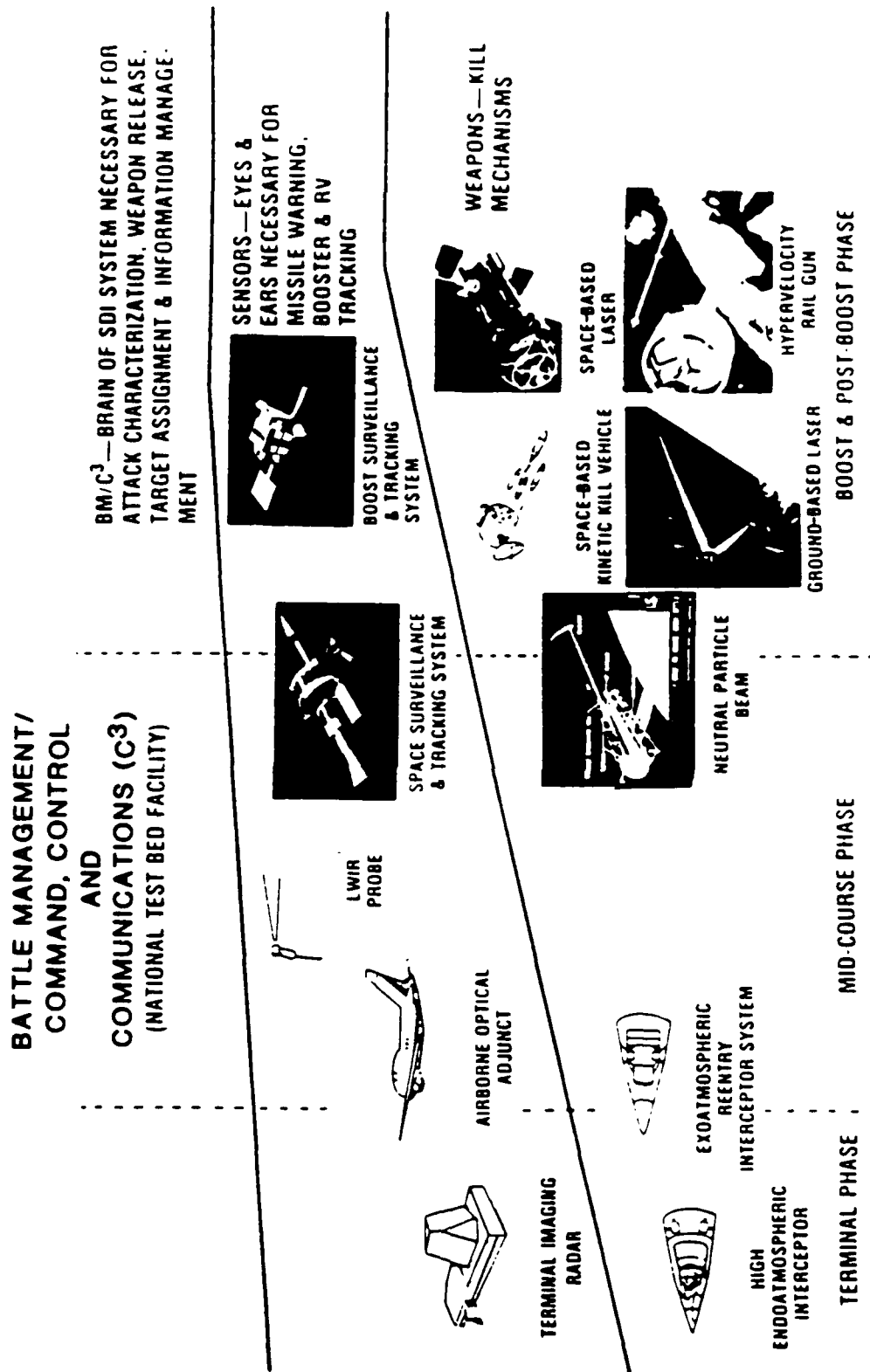


Figure II.2 Technical Concepts for the SDI

conventional weapons increased since the beginning of the SDI Program, but I am confident that SDIO efforts, by advancing such technologies as computers, guidance and control, sensors, etc., will provide new and innovative capabilities for conventional forces.

E. THE PHASED DEPLOYMENT

The technological progress that has been made on the SDI research program over the past three years has advanced at an unexpectedly fast pace, and is still accelerating. We remain convinced that the basic goal of the SDI Program is achievable. It is most likely that future decisions on deployments will have to be made on the basis of defensive options, each of which would provide increments of protection from ballistic missile attack. This progress has enabled us to examine concrete, working hypotheses about the type of defensive options that may be available in the early to mid 1990s, and has given us new insight into the contingencies that we would face were we to move to implement the fruits of our research.

This evolutionary approach to strategic defense is known as the concept of phased, or incremental, deployment. Recognizing the fact that no strategic defense system could be deployed all at once, this concept of phased deployment addresses the question of how to deploy strategic defenses in the event a deployment decision is made in the future. It does not constitute a decision to deploy. Such a decision cannot be made now. We continue to believe that the defense resulting from the various increments must be expected to meet our basic criteria. Thus, the development and deployment of the initial phase of an evolutionary system should provide a base upon which the larger, integrated system can continue to be built and should perform a militarily useful function that contributes an increase in our security commensurate with the commitment of resources involved. This would also increase arms control negotiating leverage for balanced reductions in offensive weapons.

The goals of defense deployments are: (1) Deny the Soviets confidence in the military effectiveness and political utility of a ballistic missile attack; (2) Secure significant military capability for the U.S. and its allies to deter aggression and support their mutual strategy in the event deterrence should fail; and (3) Secure a defense-dominated strategic environment in which the U.S. and its allies can deny to any aggressor the military utility of ballistic missile attack.

It has become clear that these goals can be reached through the phased deployment of defenses, and that incremental deployment of defenses is the only likely means of deployment. Each phase of deployment would be sized and given sufficient capability to achieve specific military and policy objectives and lay the groundwork for the deployment of subsequent phases. Of equal importance, the technologies employed in, and objectives served by, the initial phases of a deployment would be fully compatible with the technologies and objectives of the ultimate strategic defense system. In fact such early phases would facilitate the achievement of the ultimate system.

In addition, the first phases could serve an intermediate military purpose by denying the predictability of Soviet attack outcome and by imposing on the Soviets significant costs to restore their attack confidence. These first phases could severely restrict Soviet attack timing by denying them cross-targeting flexibility, imposing launch window constraints, and confounding weapon-to-target assignments, particularly of their hard-target kill capable weapons. Such results could substantially enhance the deterrence of Soviet aggression.

A first deployment phase could use kinetic energy weapon and sensor system technologies to concentrate on the boost-, post-boost, and late midcourse intercept layers. The boost and post-boost layers could consist of space-based kinetic-

kill interceptors combined with surveillance and targeting satellite sensors in geosynchronous orbit. The late midcourse phase intercept layer could consist of ground-launched interceptors combined with ground-launched surveillance probes and could be used to destroy nuclear weapons that are not destroyed in the boost or post-boost layer defense.

A second phase of deployment could augment late-midcourse and boost tiers with space surveillance sensors and upgraded BM/C<sup>3</sup>. Improved surveillance sensors of these systems would provide coverage of the entire missile flight. These sensors could provide an interim interactive discrimination capability against RVs and decoys. Increasing numbers of SBKKVs could provide the space-based tiers with additional self-defense capabilities against Soviet ASATs.

A third phase of deployment could endow the architecture with full strategic defensive capabilities against ballistic missiles throughout their flight trajectory. As with the previous systems, these elements would utilize highly advanced technologies developed in parallel with deployment of earlier systems. Suitable systems for this phase are advanced versions of the boost-phase sensor, improved SBKKV, advanced Space Surveillance Systems, Airborne Optical Sensors, High Endo-atmosphere Interceptors, BM/C<sup>3</sup>, and directed energy weapons for interactive discrimination of decoys and the destruction of ballistic missiles in flight.

The extent to which we would have to follow such a phased deployment approach would depend on the Soviet response. The mere development of the option for phased deployment of strategic defense can help motivate Soviet acceptance of U.S. arms reductions proposals. With such acceptance, phased deployment plans could be modified accordingly. If they respond favorably, a deployed system could function as an insurance system and would require more limited quantitative upgrading over

time. If they do not respond favorably, full deployments could be initiated.

In summary, the concept of a phased deployment of a strategic defense system appears to be feasible. An effective system of space-based and ground-based interceptors can provide a useful deterrent capability and provide strong motivation for the Soviets to cooperate in the transition from a dependence on nuclear retaliation to a greater reliance on defense. Although there are many difficult steps to be accomplished along the way and a sustained national commitment to this course of action is required, we believe that new technological options will be available to meet our criteria for incremental defense capabilities.

F. THE CONSTANCY OF THE SDIO'S MISSION AND TECHNICAL OBJECTIVES

From the very beginning, the SDIO has maintained the same goal--to conduct a vigorous research and technology development program that could help to eliminate the threat of ballistic missiles and provide increased U.S. and allied security. Within this goal, the SDIO's task is to demonstrate SDI technology and to provide the widest range of defense options possible that support a decision on whether to develop and deploy strategic defenses.

The SDIO set out without any preconceived notions of what a potential defensive system would be. Early efforts were needed to explore alternative defense architectures and provide conceptual designs of the most promising system concepts. The initial architecture studies identified how promising system concepts could be combined into effective defenses. The conceptual designs that resulted from these studies were used to estimate whether it was possible to achieve the levels of effectiveness needed in a given architecture. These studies are continuing to be used to identify the amount of research

needed to bring technology to a point where a decision on the development and deployment of strategic defenses could be supported.

G. THE MANAGEMENT CHALLENGE

Strategic defense could provide a major part of the United States' answer to an expanding Soviet threat. By establishing the SDI, the U.S. has chosen to apply its greatest asset, innovative science and engineering capabilities, to "leapfrog" the Soviet threat and render it obsolete instead of just meeting Soviet threats by responding to existing or anticipated evolutionary threats. We must, however, also maintain a hedge against Soviet ABM breakout by ensuring that the most mature technologies we are pursuing can be developed and deployed quickly if needed.

Therefore, an appropriately balanced program has several elements. First, the U.S. obviously needs to provide the technologies that yield effective defense capabilities. This requires that we pursue sensor/interceptor concepts for each phase of the ballistic missile flight and the battle management and command, control, and communications (BM/C<sup>3</sup>) capabilities to guide and manage the overall system. Balance requires not only validating technology before any decision is made to develop and deploy a defense, but also developing the technology base. The SDIO's ability to address the continually increasing Soviet capabilities rests with having a vigorous technology base effort that determines the feasibility of our most advanced defense concepts. Balancing these competing needs in a well-defined investment strategy is the essence of the management challenge.

H. THE EVOLUTION OF THE SDIO'S INVESTMENT STRATEGY

To meet its goal, the SDIO has defined a basic investment strategy with three major thrusts. First, we are bringing the most mature technologies to the point that if the decision

were made to proceed, the job of realizing the individual system concepts would be largely one of engineering. Second, the SDIO is pursuing the development of emerging technologies that have the potential for major improvements in defense effectiveness. And third, the SDIO is ensuring that an investment be made in innovative ideas that hold the promise of great success. These innovations could yield a high payoff in achieving a thoroughly reliable defense.

The SDIO's intent has been to demonstrate technical feasibility of effective strategic defense and to provide the broadest possible range of defense options to the President, the Congress, and the American people that could be achieved as quickly as possible. SDIO's budget requests were scaled accordingly. Figure II.3 plots the resources which the Administration has requested and the Congress has authorized and appropriated, as well as the shortfall in SDI funding. While the Congress has increased SDI funding every year, the difference between what the Administration has requested and what the Congress has appropriated is so large that, if this trend continues, it will have a very substantial, detrimental impact on the Program.

Large budget reductions from the FY 1985 and FY 1986 requested levels caused a reduction in the number of promising technologies being pursued in parallel and increased the difficulty of realizing adequate solutions to specific technical issues. Further reductions made in FY 1987 have placed SDIO in a position where simply scaling back alternatives is no longer viable. We are faced with either delaying the time when defenses could be deployed, if a decision is made to do so, or eliminating some technology efforts, thereby reducing the number of defense options that can support a decision. Specifically:

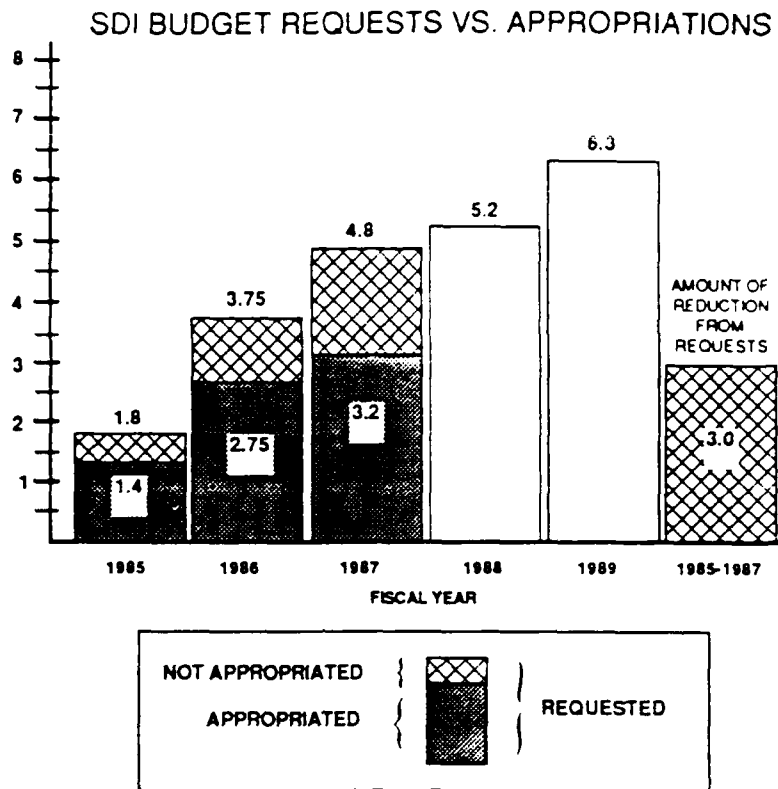


Figure II.3 (U) Congressional Funding Trends

- The progress of some portions of the SDI Program has been slowed approximately one to two years. The SDIO has, in essence, slowed its rate of progress on some technologies needed to hedge against potential Soviet countermeasures. In light of the potential Soviet threat cited above, the SDIO is extremely concerned about this slowdown. To date, despite reductions in the Administration's requests, the SDIO is still pursuing a balanced program, in which both technology base and technology validation efforts receive equal emphasis. However, the SDIO will not be able to maintain this essential balance if the trend of relatively large cuts from SDI budget requests continues.

- The SDIO has focused on the technologies that could be used to sustain performance growth to increasing levels of defense. However, effort on some technology candidates has been either reduced or eliminated. The SDIO has retained its pursuit of innovation, but at a smaller rate of investment. There are changes, some of which may be irreversible, that have lengthened the time schedule when effective defenses might be deployable and limited the technical options that will be available. In addition, by eliminating alternatives, perhaps higher-risk/higher-payoff alternatives, the risk of not achieving SDIO's goals has increased.
- The SDIO is reducing some of its programs. For example, the SATKA Program for FY 1987 originally included the Boost Surveillance and Tracking System to support the boost-phase defense tier and the Satellite Surveillance and Tracking System for the mid-course defense tier. Reductions to the FY 1987 budget request caused a choice to be made between the two systems. The BSTS was protected because it supports the high-leverage boost-phase intercept and the system is relatively mature. The same type of decision was made in the kinetic energy research program where validation work on electromagnetic launchers was cut back to support the technology validation of the more-mature chemically propelled kinetic-kill vehicles.

Even though this strategy continues to be the best of available alternatives, budget reductions have seriously reduced the Program's ability to achieve its ultimate goal. Consequently, the SDIO has requested an FY 1987 budget supplement of \$500 million and an FY 1988 budget request of \$5.2 billion to expand SDI options and reduce delays.

We have remained resolute in our decision to pursue a focused and decision-oriented program with well-defined objectives, despite Congressional refusal to fund fully the SDI budget at the requested levels. However, this goal is threatened by proposals to limit real growth to an annual 3% budget increase. Such limited funding will destroy the vital balance between development of a technology base and technology validation efforts essential to support a development and deployment decision. It will not allow us to keep pace with expected Soviet offensive and defensive developments. If SDI funding continues to be limited, the U.S. will not only waste its greatest leverage--the innovation possible in a free society--but it cannot expect to do more than react to Soviet initiatives in strategic defense. If U.S. efforts to provide a thoroughly reliable defense are to be successfully carried out in a timely fashion, funding must be restored to levels that will allow the SDIO to effectively pursue options for strategic defense of the U.S. and its allies.

### CHAPTER III

#### PROGRAM IN PERSPECTIVE

##### A. THE STRATEGIC CONTEXT

The basic objectives of the SDI are best explained and understood in terms of the strategic environment the United States faces for the balance of this century and into the next. The U.S. and its allies face a number of challenges that threaten our security. Each of these challenges imposes demands and presents opportunities. Preserving peace and freedom is, and always will be, this country's fundamental goal. The essential purpose of U.S. military forces is to deter aggression, threats of aggression, and coercion against the U.S. and its allies. The deterrence provided by U.S. and allied military forces in the past has permitted the American people and their allies to enjoy peace and freedom.

For the past 20 years, assumptions of how nuclear deterrence can best be assured have been based on a theoretical concept. This concept holds that if the U.S. and U.S.S.R. both maintain the ability to retaliate against nuclear attack, and if the U.S. could impose on the Soviet Union costs that are clearly out of balance with any potential gains, this threat would suffice to prevent nuclear war. The estimate of what Soviet assets must be held at risk by U.S. forces to deter aggression has changed over time. Nevertheless, the strategy of relying on retaliation provided by offensive nuclear forces as the essential means of deterring aggression has not changed. This assumption served as the foundation for the U.S. approach to the Strategic Arms Limitation Talks (SALT). At the time the process began, the United States concluded that deterrence based on the mutual capability of offensive retaliatory forces was not only sensible but necessary. The U.S. believed that both sides were far from being able to develop the technology for defensive systems which could effectively deter the other side. However, the Soviet Union

has failed to show the necessary restraint, in both strategic offensive and defensive forces, that was an essential assumption of the U.S. strategic concept when the SALT process began.

The U.S. response to the strategic threat has, out of necessity, undergone a period of evolution during the last three decades to adapt to the changing nature of the threat itself. The current strategic environment is characterized by (1) improvements in Soviet strategic offensive and defensive forces, (2) a long-standing and intensive Soviet research program in many of the same basic technological areas which the SDI Program addresses, and (3) a growing pattern of Soviet deception and noncompliance with existing arms control agreements.

#### B. THE CHALLENGE TO U.S. SECURITY

The Soviet Union remains the principal threat to U.S. security and that of our allies. As part of its wide-ranging effort to increase further its military capabilities, the Soviet Union has improved its ballistic missile force, increasingly threatening the survivability of U.S. and allied deterrent forces and the leadership structure that commands them. Soviet forces equally threaten many critical-fixed installations in the United States and in allied nations that support the nuclear retaliatory and conventional forces which provide the collective ability to deter conflict and aggression.

Since 1969, when the SALT I negotiations began, the Soviet Union has built five new types of ICBMs and upgraded them seven times. The Soviet Union also has built seven new classes of ballistic missile submarines and built five new types of SLBMs and upgraded them three times. As a result, their missiles are much more powerful and accurate than they were several years ago. The United States, in contrast, has just introduced the Peacekeeper, the first new ICBM deployed

since the Minuteman III was introduced in 1969. The United States also is dismantling its obsolete Titan missiles. With respect to sea-based ballistic missile forces, the U.S. has deployed, since 1969, only one new class of ballistic missile submarine and two new types of SLBMs. The alarming growth, both in quantity and quality, of Soviet ballistic missiles over the past decade is yielding a prompt hard-target force capable of rapidly and significantly degrading our land-based retaliatory capability. The resulting asymmetry between Soviet and U.S. forces has led to a destabilizing situation, one that the Reagan Administration strongly believes must be redressed.

At the same time that it has worked to improve its offenses, the Soviet Union has continued to pursue strategic advantage through the development, improvement, and expansion of Soviet active defense capabilities. These active defenses provide the Soviet Union with a steadily increasing capability to counter the retaliatory forces of the U.S. and its allies, especially if those forces were to be degraded by a Soviet first strike. Furthermore, current patterns of Soviet research and development on advanced defenses indicate that these trends will continue apace for the foreseeable future. If unanswered, continued Soviet defensive improvements will further erode the effectiveness of the United States' existing deterrent, based almost exclusively on the threat of retaliation by offensive nuclear forces. Therefore, this long-standing Soviet program of defensive improvements, in itself, poses a challenge to the basis for deterrence which must be addressed.

Today, Soviet active defenses are extensive. The Soviets have the world's largest air defense network, which they vigorously continue to improve, and the world's only operational ASAT capability. The Soviet Union also possesses the world's only operational ABM system, which is deployed around Moscow. The Soviet Union currently is improving all elements of this system. The Soviets are also developing new ABM components

that could allow construction of individual ABM sites in a matter of months rather than in the years usually required for older ABM components. It also has a very extensive and expanding network of ballistic missile early-warning radars.

The Soviet Union is also spending significant resources on passive defensive measures aimed at improving the survivability of its forces, military command structure, and national leadership. These efforts range from providing mobility for its latest generation of ICBMs to extensive hardening of various critical military and civil defense installations. All of these active and passive elements taken together provide the Soviet Union an area of relative advantage in deployed defensive capability and near-term defensive deployment options.

Finally, Soviet noncompliance with arms control agreements in both the offensive and defensive areas, including the ABM Treaty, is of very serious concern. The new Soviet phased-array radar under construction near Krasnoyarsk, in central Siberia, has significant consequences. When considered as a part of a Soviet network of new radars, the Krasnoyarsk radar has the inherent potential to contribute to ABM radar coverage of a significant portion of the central U.S.S.R. Recognizing that such radars could make that contribution, the ABM Treaty expressly bans construction of early warning LPARs at interior locations as one of the primary mechanisms for ensuring the effectiveness of the Treaty. Due to its location and orientation, this radar is in direct violation of the ABM Treaty.

Against the backdrop of this Soviet pattern of non-compliance with existing arms control agreements, the Soviet Union is also taking other actions which affect this country's ability to verify Soviet compliance. Some Soviet actions, like increased use of encryption during missile testing, are aimed directly at degrading the U.S. ability to monitor treaty

compliance. Other Soviet actions contribute to the problems that must be faced in monitoring Soviet compliance. For example, increases in the number of Soviet mobile land-based strategic, intermediate-, and short-range ballistic missiles will make verification far more difficult.

If the United States fails to respond to these trends, there may come a point in the foreseeable future when the U.S. would have little confidence in its assessment of the military balance or imbalance. This could limit U.S. ability to control escalation during a crisis.

C. THE RESPONSE TO THE CHALLENGE

In response to the long-term pattern of Soviet offensive and defensive improvements, the United States is compelled to take complementary actions designed both to maintain security and stability in the near term and to ensure these conditions in the future. It must act in three main areas.

First, offensive nuclear retaliatory forces must be modernized. This is necessary to reestablish and maintain the offensive balance in the near term and to create the strategic conditions that will permit the U.S. to pursue complementary actions in the areas of arms reduction negotiations and defensive research. In 1981, the U.S. embarked on a strategic modernization program aimed at reversing a long period of relative neglect. This modernization program was specifically designed to preserve stable deterrence and, at the same time, to provide the incentives necessary to cause the Soviet Union to join the U.S. in negotiating significant reductions in the nuclear arsenals of both sides.

In addition to the U.S. strategic modernization program, NATO is modernizing its longer-range intermediate nuclear

forces (LRINF). Our British and French allies also have under way important programs to improve their strategic nuclear retaliatory forces. The SDI research program does not negate the need for these U.S. and allied programs. Rather, the SDI Program depends upon collective and national modernization efforts to maintain deterrence today as options are explored for possible future decisions on how the U.S. might enhance security and stability over the longer term.

Second, steps must be taken to provide mid-to-future options for ensuring deterrence and stability over the long term, allowing the U.S. to counter the destabilizing growth of Soviet offensive forces and to channel long-standing Soviet propensities for defenses toward more stabilizing and mutually beneficial ends. The Strategic Defense Initiative is specifically aimed at achieving these goals. In the near term, the SDI Program also responds directly to the ongoing and extensive Soviet antiballistic missile effort, including the existing Soviet deployments permitted under the ABM Treaty. The SDI research program provides a necessary and powerful deterrent to any near-term Soviet decision to rapidly expand its antiballistic missile capability beyond that permitted by the ABM Treaty. This, in itself, is a critical task. However, the overriding, longer-term importance of the SDI is that it offers the possibility of reversing the dangerous military trends cited here by moving to a better, more stable basis for deterrence and by providing new and compelling incentives to the Soviet Union for seriously negotiating reductions in existing offensive nuclear arsenals.

In our investigation of the potential of advanced defensive systems, the U.S. seeks neither superiority nor unilateral advantage. Rather, if the promise of SDI technologies is proven, the destabilizing characteristics of the current strategic environment could be rectified. And, in the process, deterrence would be strengthened significantly and placed on a

foundation made more stable by reducing the role of ballistic missile weapons and placing greater reliance on defenses that threaten no one.

Third, the U.S. must continue its strong commitment to arms control. The near-term objective is to radically reduce offensive nuclear arms, as well as to make safer the relationship between nuclear offensive and defensive arms. We are now looking forward to a period of transition to a more stable world with greatly reduced levels of nuclear arms and an enhanced ability to deter war based upon the increasing contribution of nonnuclear defenses against offensive nuclear arms. A world free of the threat of aggression and free of nuclear arms is an objective on which the U.S., the Soviet Union, and all other nations can agree.

To support these goals, this country will continue to pursue vigorously the negotiation of equitable and verifiable agreements leading to significant reductions of existing nuclear arsenals and the eventual elimination of all ballistic missiles, as proposed by the President. Simultaneously with negotiations, the U.S. will continue to exercise flexibility concerning the mechanisms used to achieve these goals but will judge these mechanisms on their ability to enhance U.S. and allied security, improve strategic stability, and reduce the risk of war.

If the SDI Program yields positive results, the U.S. will consult with its allies about the next steps. Unless the U.S. and Soviet Union already have agreed to a specific, comprehensive arms control plan to reduce or eliminate ballistic missiles and deploy defensive forces, the United States would also consult and, as appropriate, negotiate with the Soviet Union pursuant to the terms of the ABM Treaty which provides for such consultations. These negotiations and consultations would focus on how deterrence might be strengthened through

the phased introduction of defense systems into the force structures of both sides. This commitment does not mean that the United States will give the Soviets any veto over a future U.S. decision on strategic defense. In anticipation of a possible future decision to deploy defenses, the U.S. has already begun the process of bilateral discussions with the Soviet Union. The U.S. and U.S.S.R. have met in Geneva, Reykjavik, and Vienna to address questions which included those related to the U.S. objective of a jointly managed transition integrating advanced defenses into the forces of both sides.

D. THE ROLE OF THE STRATEGIC DEFENSE INITIATIVE

In summary, the President's Strategic Defense Initiative is an important effort to fundamentally improve the longer-term security of the U.S. and its allies and to provide a better response to the growing Soviet offensive and defensive threat. Recent advances in defensive technologies warrant a new evaluation of ballistic missile defense as a basis for a safer form of deterrence, more consistent with U.S. values. Possibilities for maintaining security by means of an enhanced ability to deter war through an increasing capability to defend against attack--rather than through sole dependence on the threat of nuclear retaliation--deserve, and are receiving, serious exploration.

## CHAPTER IV

### GOALS AND TECHNICAL OBJECTIVES

#### A. INTRODUCTION

This section describes how the SDI Program is executed, its program goals, how these goals are being turned into program requirements, how these requirements can be met, and the overall investment (funding) strategy.

#### B. GOALS

The SDIO's goal is to conduct a program of vigorous research and technology development needed to establish strategic defense options that could eliminate the threat posed by ballistic missiles. The primary capabilities of a given defense option are that it can potentially:

- Support a better basis for deterring aggression,
- Strengthen strategic stability, and
- Increase the security of the United States and its allies.

The SDI Program seeks to provide the technical knowledge required to support an informed decision on whether to develop and deploy a ballistic missile defense system for the U.S. and its allies.

Program success in meeting this goal should be measured according to the options' abilities to (1) counter and discourage the Soviets from continuing the growth of their offensive forces and (2) channel long-standing Soviet propensities for defenses toward more stabilizing and mutually beneficial ends. Furthermore, the SDI Program is charged with providing in the near term a definitive response to the Soviets' vigorous advanced antiballistic missile research and development effort.

Thus, the SDI could act as a powerful deterrent to any near-term Soviet decision to expand rapidly its antiballistic missile system beyond that permitted by the ABM Treaty. Nonetheless, the overriding, long-term importance of the SDI is that it offers the possibility of reversing dangerous Soviet military trends by moving to a better and more stable basis for deterrence. It could provide new and compelling incentives to the Soviet Union for serious negotiations on reductions in existing offensive nuclear arsenals.

There have been no preconceived notions of what an effective defensive system against ballistic missiles should be. In keeping with the SDIO mission to provide the most effective strategic defense options, a number of different concepts involving a wide range of technologies are being examined.

#### C. BASIC REQUIREMENTS

A strategic defense system that would devalue offensive ballistic missiles to a meaningful degree, and therefore would be an appropriate result of the Strategic Defense Initiative Program, would have to meet the same three specific standards that any other military system would require.

The first requirement is military effectiveness. A defense against ballistic missiles must be able to destroy a sufficient portion of an aggressor's attacking force to deny him confidence that he can achieve his objectives. In doing so, the defense should have the potential to deny that aggressor the ability to destroy a militarily significant portion of the target base he wishes to attack. Furthermore, if a deployed defensive system is to have lasting value, technology and tactics must be available that would allow the system to evolve over an extended period to counter any plausible responsive threats. Such a robust defense should have the effect of deterring a strong offensive response and enhancing stability.

The second requirement is adequate survivability. Defenses must maintain a sufficient degree of effectiveness to fulfill their mission, even in the face of determined attacks on the defenses and, perhaps, loss of some individual components. Such a capability will maintain stability by discouraging such attacks. Survivability means that the defensive system must not be an appealing target for defense suppression attacks. The offense must be forced to pay a penalty if it attempts to negate the defense. This penalty should be sufficiently high in cost and/or uncertainty in achieving the required outcome that such an attack would not be contemplated seriously. Additionally, the defense system must not have an "Achilles heel." In the context of the SDI, survivability would be provided not only by specific technical "fixes" such as employing maneuver, sensor blinding, and protective shielding materials, but also by using such strategy and tactical measures as proliferation, deception, and self-defense. System survivability does not mean that each and every element of the system need survive under all sets of circumstances; rather, the defensive force as a whole must be able to achieve its mission, despite any degradation in the capability of some of its components.

The third requirement is that options generated by research be evaluated to the degree that the defensive systems discourage an adversary to overwhelm them with additional offensive capability. The SDIO seeks defensive options--as with other military systems--that are able to maintain their defense capabilities more easily than countermeasures could be taken to try to defeat them. This criterion is couched in terms of cost-effectiveness at the margin; however, it is much more than an economic concept.

#### D. DEFENSIVE OPTIONS

If the SDI is to support future decisions on selecting defensive options, diverse efforts producing essential answers

to critical issues must converge. Promising affordable ballistic missile defense architectures must be identified. The technical feasibility and readiness for development of survivable and cost-effective systems capable of meeting and sustaining the performance needs of those architectures must be established. The doctrine and concepts of operation for applying the system elements of the preferred architectures must be formulated. Practical alternatives for implementing the strategy and deploying defenses in the context of foreign relations and arms control must be defined.

Since FY 1984, the SDIO has pursued efforts to identify the above requirements through the system architecture and concept definition studies. The purpose of these studies is threefold. The first is to provide an initial definition and assessment of several alternative system architectures that can detect, identify, discriminate, intercept, and negate ballistic missiles in their boost, post-boost, midcourse and/or terminal phases. A second purpose is to provide a complete and balanced set of technological and functional requirements needed to define conceptually the individual systems within the architectures. This is accomplished by identifying the key trade-offs for interfaces among the sensors; weapons; and command, control, and communications systems that can make the individual architecture viable and cost-effective. A third purpose is to define and prioritize critical technical issues that must be resolved to ensure that such systems can meet the performance demands of a given architecture. These three inputs are key to understanding how future decisions can be made on whether or not to implement a given defensive strategy.

The task of identifying reasonable defense architectures and system concepts is an ongoing one. The evaluation and analysis of SDI technologies and designs must necessarily evolve as research progresses. Two important elements are integral to this task: (1) the analysis of potential respon-

sive threats with which a proposed defense would have to cope and (2) the development of appropriate scenarios for use in simulations and evaluations.

The value of this ongoing research, even at the generic level, should not be underestimated. The study of possible systems allows the SDIO to identify critical problem areas, develop measures of system effectiveness, and evolve new concepts. Without these steps, the SDIO could not prioritize its investments. In addition, useful trade-off studies are being performed that may, among other outputs, allow the SDI to discover possible synergistic relationships between subsystems, major system elements, and strategies.

#### E. TECHNICAL OBJECTIVES

If the SDIO is to offer a high-confidence basis for decisions whether to pursue one or more defensive options, the Program must do several things. First, it must conduct a balanced effort that expands and accelerates the progress of technology in a manner that supports the relevant architectures. Second, it must provide the architect with conceptual designs of the system elements. Such designs are needed if the architect is to evaluate the potential effectiveness of candidate ballistic missile defense that could be assembled and deployed from those technologies. Third, it must provide a basis for showing how those defense options can be operated and maintained to do the job. These activities are being conducted in accordance with applicable U.S. treaty obligations.

The SDIO must pursue its Program in a logical and timely way and balance its efforts between advanced and more mature technologies. First, the most mature technologies need to be validated in order to provide initial options for defense architectures. These options could simply hedge against Soviet breakout and deployment of a defense against U.S. ballistic missiles or provide a defense against the current and

potential 1990s Soviet offensive threat. Second, the long-term viability of future defensive options needs to be ensured by demonstrating the feasibility and readiness of technologies to support more advanced defense options against an evolving and increasingly more capable threat based on the offensive technologies of the early 21st Century. And third, research needs to be conducted in a manner that encourages innovation by the U.S. scientific community in response to the President's challenge to aid the SDIO in identifying and exploiting new approaches promising major gains in defense effectiveness.

F. BASIC PROGRAM ACTIVITIES

SDIO has established a program that is designed to gain and maintain the initiative for defenses against ballistic missiles. The SDIO will achieve this by means of the following activities:

- Technology base development which could evolve faster than potential responses in Soviet ballistic missile capabilities.
- Technology validation consisting of major experiments that determine readiness to proceed with full-scale development. This activity includes technology integration experiments and system-level validation experiments.

The scientific work in the SDIO that is classified as a technology development activity encompasses a large number of individual efforts, i.e., programs with small to modest funding. The work is comprised of both basic and applied research. Some of this work involves relatively straightforward extensions of existing technology; it also includes high-risk, but high-payoff, efforts. The technology development activity is intended to foster the birth of many innovative ideas. The programmatic objective is to provide the framework of knowl-

edge needed to pursue integrated experiments and to build opportunities for program growth, particularly in those disciplines that might have far-reaching impact.

To focus and integrate this evolving technology, key projects have been chosen that are designed to provide the needed technology base for validation of critical elements of an SDI system. Examples of these technology development efforts are scaling experiments for a laser device, development of new infrared (IR) sensor materials, study of lightweight shielding material to protect both boosters and spacecraft from laser attack, research into large structures to be used in space, and creation of advanced software engineering techniques that are more feasible and testable.

Technology validation, the second major activity, includes proof-of-feasibility experiments. These experiments tend to be moderately expensive, driven by time urgency, and focused on the problems of technology and systems integration. The emphasis in these projects is on the early resolution of a major issue that can have a substantial impact on the success of the long-term SDI goal. Examples of such projects are the integration of a high-power free electron laser and beam director, a study of a space-based neutral particle beam accelerator and sensor package, a booster tracking and weapon platform pointing experiment, and an integrated study of kinetic energy intercept of a target vehicle in outer space.

Technology validation experiments (TVEs) also include efforts to prove system-level feasibility, preceding full-scale development. Examples of these projects are simulation of test beds to demonstrate capabilities in tracking missiles in the boost phase and discriminating decoys from warheads and hit-to-kill exoatmospheric and endoatmospheric intercept. These experiments involve technology that has already been demonstrated as feasible and must now be integrated with other

subsystem requirements. These projects are characterized by emphasis on integration of constituent elements and the performance of functional tests. Experiments in this phase give some understanding of a group of unknowns that must be explored before any degree of confidence can be given to development and then deployment. These experiments are expensive and time consuming. On the other hand, integration and further testing offer ways of avoiding more costly mistakes that often occur due to premature decisions to test and develop complex, previously untested concepts. If the technology base is limited excessively by budget cuts, then the technical risk for these projects may become unacceptably high, i.e., there may be limited flexibility for exploring other alternatives to assure project success. These experiments are sensitive to and are driven by fiscal and time constraints.

Examples of major technology integration experiments include:

- Boost Surveillance and Tracking System (BSTS),
- Space-Based Kinetic-Kill Vehicle (SBKKV),
- High Endoatmospheric Defense Interceptor (HEDI), and
- Exoatmospheric Reentry Vehicle Interceptor System (ERIS).

In addition, the National Test Bed (NTB) is an example of a system-level validation experiment that is part of technology validation. These activities reflect SDI emphasis on critical path programs oriented toward resolving the key technical issues required to support development and deployment decisions. These activities will also provide a timely, visible, and understandable set of milestones with which to measure program progress and accomplishments. The key to the success

of this approach is to incorporate multiple alternatives to satisfy the requirements for successful defense architectures and thus avoid single point failures.

G. INVESTMENT STRATEGY

Establishing a viable investment strategy for the SDIO's two basic research activities--technology development and technology validation efforts--has been of major importance, as these priorities have undergone constant reevaluation due to the large budget reductions imposed by the Congress.

The current investment strategy is to maintain program balance by:

- Protecting the technology base,
- Increasing the emphasis on TVEs with increased investment in the high-risk, high-payoff approaches, and
- Decreasing the number and scope of alternative projects.

In this approach one must guard against the technology base activity turning into what has been termed in other cases "technological filibustering," that is, rejecting the "good enough" in search for something "better." The positive view, of course, is that the SDIO would develop a better end product, one that gives the U.S. the kind of leverage necessary to make defenses work reliably, robustly, and at a reasonable cost. There will admittedly need to be a constant vigil over the priorities set between technology development and validation experiments. The Program can neither afford to pursue "science for the sake of science" nor afford to proceed with risky experiments having an inadequate technology base.

#### H. BASIC PROGRAM STRUCTURE

With this priority-setting philosophy in hand, the Program is logically divided into Program Elements that address the basic functions of a strategic defense system. The SDIO's technology programs include Directed Energy Weapons and Kinetic Energy Weapons, which involve research that addresses issues related to the intercept of targets; Surveillance, Acquisition, Tracking, and Kill Assessment, which addresses issues related to sensing targets; and Survivability, Lethality, and Key Technologies, which supports the other programs by doing research in critical technology that applies to all functions of a strategic system. In addition, the Systems Analysis and Battle Management program conducts research aimed at creating system concepts and command, control, and communications to manage the system. There are ancillary areas that address the threat and threat projections, in addition to an activity to stimulate innovative science and technology.

The priority decisions that affect the technology programs are driven by systems requirements, including possible Soviet responsive threats. The systems analysis projects, such as the architecture studies and the Red Team/Blue Team countermeasures, engage in studies to uncover problems and allow for definition of the critical issues. Such areas give the Program general guidance and, when properly coupled through appropriate feedback loops to and from the technical programs, provide a strong focus for the overall SDI Program. These activities basically define the issues that the technology programs must resolve. They also help define the priorities in the face of limited resources.

In the area of countermeasures, the SDIO has set up Red/Blue technical teams to analyze SDI systems and possible countermeasures and counter-countermeasures. The SDIO is also attempting to simulate the high-level Soviet government response by establishing a mock Politburo. This approach

will provide greater insight into possible Soviet responses to a defense deployment.

I. TECHNICAL DEVELOPMENT PACE

A notional schedule for research and possible development and deployment would comprise four periods:

- The research-oriented program, begun by the President in his 1983 Initiative, would continue until a decision could be made by a future President and Congress on whether to enter into full-scale engineering development (FSED).
- Full-scale development of a first-phase defense system. Work on more advanced defensive technologies would continue.
- A transition period of phased deployment of defensive systems. These phased deployments would be designed so that each added increment would further enhance deterrence and reduce the risk of nuclear war. Preferably, this transition would be jointly managed by the U.S. and the Soviet Union, although such Soviet cooperation would not be a prerequisite for initiation of U.S. deployments.
- Finally, a period of time during which deployment of highly effective, multilayered defensive systems would be completed. Such deployments could enhance significantly the prospects for negotiated reductions, or even the elimination of offensive ballistic missiles.

The research-oriented period of the Program is focused on bringing defense options to the point where U.S. leaders, after consultation with the allies, could make decisions on

whether to proceed with development and deployment. The technology should be sufficiently mature before proceeding with confidence along a development path toward a first-phase defense system. In other words, most of the effort on a first-phase system should be in the nature of engineering development, rather than that of exploratory research and technology base. The best technical approach should have been selected by means of a thorough trade-off analysis. This involves the identification of alternatives; examination of their feasibility; and comparison in terms of performance, cost, technical risk, and development time. Cost and schedule estimates should be credible and acceptable.

CHAPTER V  
PROGRAMS AND SYSTEMS PERSPECTIVES

A. INTRODUCTION

The interfaces between systems and technology in the SDI Program are broad and complex, both managerially and technically. For this reason, as part of an overall SDIO reorganization, the Systems Directorate was reorganized as the Programs and Systems Deputate with seven directors reporting to the Deputy (see Figure V.A.1). This provides greater visibility and higher-level management attention to critical functions that must be performed efficiently and effectively in support of the SDI Program. Similarly, a Deputy for Technology was established in the reorganization to provide a focal point for the SDI technology efforts, with the exception of that for Battle Management/C<sup>3</sup>. Because of its unique role in defining an SDI system architecture, the BM/C<sup>3</sup> technology responsibility was assigned to Programs and Systems.

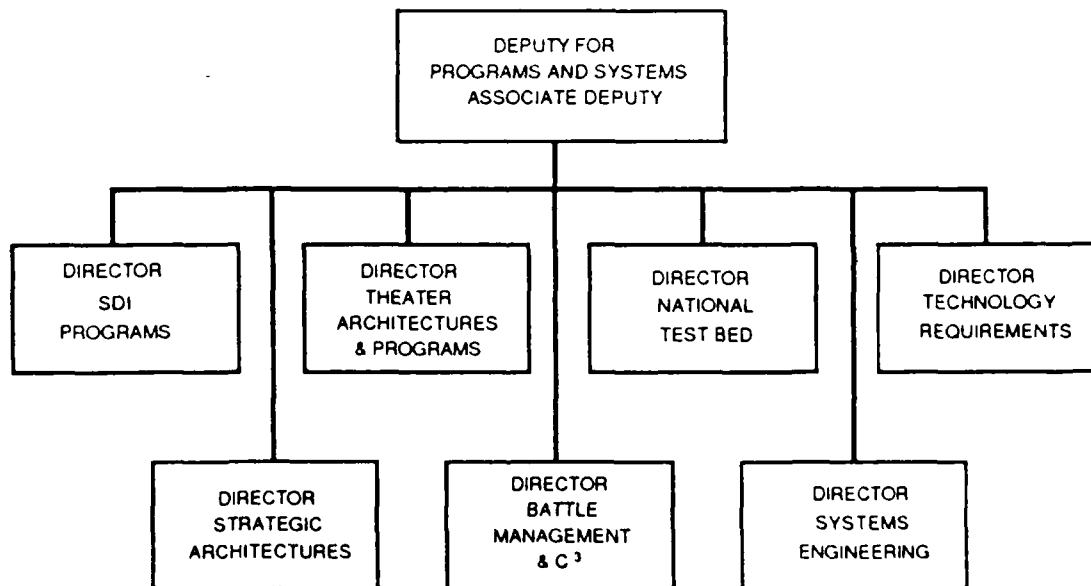


Figure V.A.1 Programs and Systems Deputate Organization

The Deputy for Programs and Systems is responsible for providing overall direction and identifying technical requirements for all elements of the SDI Program. Systems analyses are central to identifying the major elements that make up candidate defense architectures as well as deriving the performance requirements of these elements. Three fundamental candidate defense architectures have emerged from these efforts: a space- and ground-based strategic architecture, a ground-based strategic architecture, and a theater defense architecture. The performance requirements determined for these architectures provide the basis for focusing the technology program and for establishing the framework within which the various technologies may be integrated into a system that will achieve the SDI mission. This process provides the opportunity to investigate the full range of technical issues and problems. Finally, it provides the framework to bring expert judgment to bear on the alternative approaches to achieving effective defenses and the design and development of the weapons systems that would constitute those defenses.

The functions performed by the seven Programs and Systems directors are described in the following paragraphs.

Director, SDI Programs. This directorate is responsible for developing the overall investment strategy of the SDI Program and ensuring that a balance is maintained between technology development and technology validation, especially when adjustments to reduced funding levels are required. The investment strategy is continually reviewed and adjusted in view of evolving architecture requirements and progress in the technology programs.

Director, Strategic Architecture. This directorate is responsible for the ongoing development and evaluation of strategic architecture concepts, elements, and trade-offs.

Included in this effort is mission analysis and evaluation of the architecture concepts to responsive threats.

Director, Theater Architectures and Programs. Potential regional (theater) defense architecture concepts were developed by contractors during phases I and II of the architecture efforts. Recognizing the important contribution a regional defense makes to the security of U.S. allies, a separate directorate has been formed to manage this vital aspect of the SDI Program. There will be substantial allied involvement in this part of the Program.

Director, Battle Management & C<sup>3</sup>. This directorate is responsible for the development of BM/C<sup>3</sup> concepts, architectures, and technologies to support a strategic defense. Additionally, this directorate is responsible for the design and conduct of experiments (both ground- and space-based) to validate the BM/C<sup>3</sup> concepts, architectures, and technologies.

Director, National Test Bed. This directorate is responsible for the development and integration of the NTB as a comprehensive capability to evaluate, test, and compare candidate strategic architectures and elements of a multilayered defense. It will provide the capability to emulate the BM/C<sup>3</sup> function and will include an Allied Test Bed as an adjunct to evaluate, test, and compare regional (theater) defense concepts and elements.

Director, Systems Engineering. This directorate is responsible for pursuing system trade-offs, industrial base analyses, logistics, and supportability efforts as well as cost research. Included will be the development of the criteria that must be satisfied in support of an FSED decision.

Director, Technology Requirements. This directorate is responsible for identifying and assessing technology require-

ments based primarily on system architectures and providing the requirements interface with the Technology Deputate. In this way, the technology directors can assess and redirect the technology efforts to support the evolving architecture requirements. At the same time, this directorate will feed back the technical progress being made for review and assessment on the part of strategic architectures, regional (theater) architectures, and systems engineering.

The next several sections describe the SDI Programs and Systems efforts in greater detail.

## B. SDI PROGRAMS

The SDI Programs Directorate is responsible for planning, coordinating, analyzing, and reporting on the objectives, strategy, and implementation of the SDI Program.

### Program Planning

This activity assures that the SDI research program is defined in terms of established system concepts and architectural descriptions as identified by the Strategic and Theater Architecture Directorates and the Technology Directorates. An integrated technical program plan, which includes data from architecture, technology developments, and technology validation projects, is developed to portray the current status of the research program. In addition, long-range plans and strategies are created to support the evolution of strategic defense architectures. System validation tests are identified that meet the criteria for full-scale development decisions on strategic defense options.

### Program Coordination

This activity accomplishes, in conjunction with the SDIO Comptroller, the requirements of the DoD Planning, Programming, and Budgeting System (PPBS). Overall prioritized research budgets are formulated on the basis of architecture requirements and technology issues. These budgets are coordinated with other SDIO directorates to arrive at funding levels required to balance technology development with technology validation projects that can meet Program objectives and goals.

### Program Analysis

Because of the variety of research projects, critical paths leading to an appropriate balance between technology development and technology validation need to be identified across all SDI projects. This activity assesses the risk involved in research aimed at resolving systems issues to

recommend lower-risk alternatives where possible. These analyses are used to develop ways to meet objectives and timelines in the face of fiscally constrained budgets.

#### Program Reporting

A key activity in the SDI Programs Directorate is developing information to portray the SDI research program in terms of its technical content and progress toward meeting objectives and goals. Technical progress reports, program planning guidance documents, and testing and facilities plans are developed to explain and guide the Program. Integrated technical program plans and long-range planning options are used to form an overall investment strategy for the SDI Program.

### C. STRATEGIC ARCHITECTURES

#### Systems Analysis Process

The systems analysis project provides overall SDI system-level guidance to weapon, sensor, BM/C<sup>3</sup>, and supporting technologies being developed under the SDI. It is oriented toward providing a quantifiable basis for programmatic decisions on the SDI elements. The process for accomplishing this involves a highly iterative systems analysis process which is shown in Figure V.C.1.

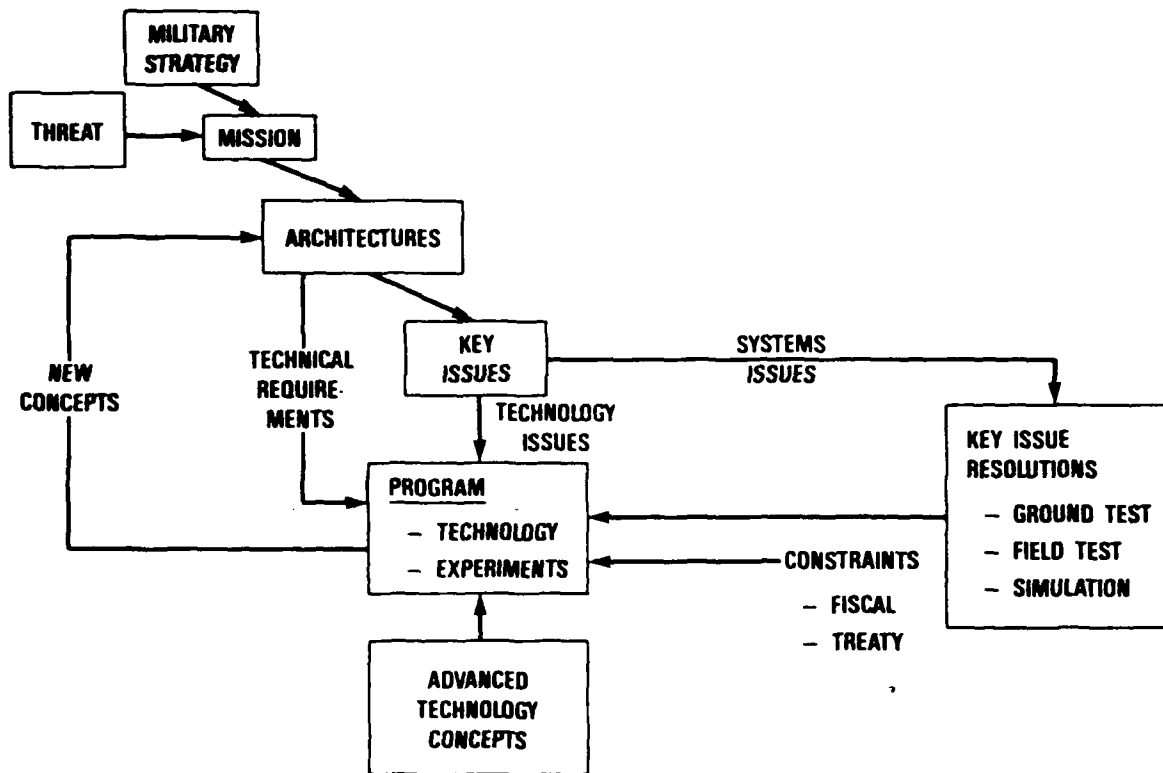


Figure V.C.1 Systems Analysis and Program Requirements Process

The systems analysis process starts with the definition of a defense system architecture. This establishes the context within which various technologies may be integrated into a system that will achieve the SDI mission. Once a candidate defense system architecture is defined, the performance requirements of the defense subsystems may be established, and

through that process the SDI Program requirements for developing those technologies may be determined. In establishing the defense subsystem performance requirements, various tactics and strategies on the part of the offense and defense must be evaluated. On the offensive side, special consideration must be given to defense suppression attacks, defense avoidance, etc. On the defensive side, emphasis must be placed on configuring the candidate defensive subsystems in a manner to optimize the overall performance of the defense.

The analysis of the effectiveness of a candidate defense architecture leads to a definition of the technical requirements of the subsystems comprising the architecture and identifying key issues that must be resolved to make that architecture viable. These key issues may be technology-related or system-related issues, and their resolution is accomplished by some combination of ground test, field test, and simulation.

The systems analysis process itself has remained constant since the FY 1986 Report to the Congress on the SDI. The fundamental process is being applied to both strategic and regional (theater) defense systems.

Considerable progress has been made in three major areas since the last report:

- Development of baseline threats and threat scenarios for use in the system simulations,
- Identification of key system issues and strategies for their resolution, and
- Development of architecture framework with three classes of systems showing concepts and ranges of performance requirements.

Within the architectural framework, additional studies have been initiated to define support systems logistics approaches, and software implementation alternatives. The interest in these areas is to provide a better understanding of the technical cost constraints imposed on the architectures by these areas.

#### Strategic Architecture Examples

An important objective of the SDI is the pursuit of several candidate architecture options and the promotion of advanced technology concepts which could form the basis for new architectural options.

This objective is being supported in the strategic architecture by utilizing multiple competitive architecture teams to develop and examine in increasing depth candidate architecture options. The process to date has produced three classes of architecture (each containing multiple options):

- A combined architecture class utilizing space-based and ground-based sensors and weapons,
- A ground-based KEW architecture class, and
- Architectures to counter the shorter-range tactical ballistic missiles which are a particular threat to U.S. and allied deployed forces.

Figure V.C.2 displays this architecture class which uses a space-based directed energy weapon as a discriminator. In this representative architecture, system alert is provided by one or more of a small number of boost-surveillance satellites. These satellites serve an alerting role and provide initial boost track. Otherwise they serve only an alerting role. A second set of satellites for space surveillance provide essential acquisition, tracking, and discrimination

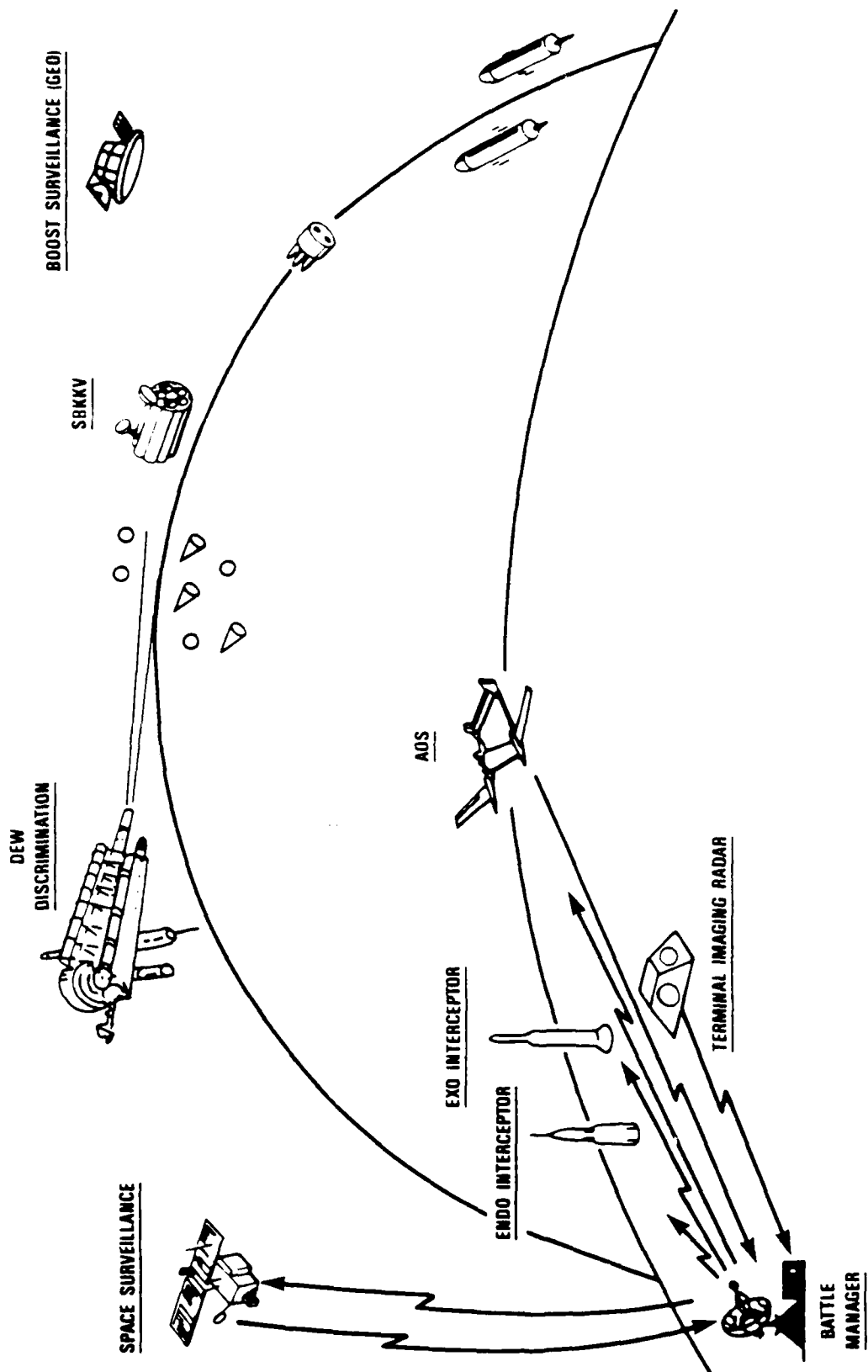


Figure V.C.2 An Example of a Nonnuclear Ground- and Space-Based Architecture (DEW Discrimination)

functions. These satellites must therefore be located, proliferated, and defended in such a way as to have their function survive a defense suppression attack.

The process of rapidly forming system track information on each of the elements seen by the sensors poses a formidable challenge to both technology developers and systems architects. Increased effort to address this is the focus of the SDIO's program in battle management technologies and system architectures.

Space-based kinetic-kill vehicles, SBKKVs, engage the threat in the boost, post-boost, or midcourse phase of its trajectory. The kill vehicles are required to attack essentially all boosters or reentry vehicles in midcourse if the RVs are unaccompanied by large numbers of penetration aids. The kill vehicles are dispersed over many platforms to counter defense suppression attacks. SBKKV platforms must defend themselves as well as other space assets from potential space-based threats.

In addition to defense suppression, a responsive offense can shorten the burn time of the ballistic missile booster, depress the trajectory to diminish the effectiveness of intercept in the boost or post-boost phases, and proliferate penetration aids to overwhelm the defense during the midcourse phase. The desirability of achieving high confidence in effective midcourse discrimination promotes the consideration of using directed energy weapons (or even kinetic means) to modify the behavior or signature of the penetration aids in order to identify them.

Finally, a terminal defense must effectively engage the RVs which leak through the space-based and midcourse engagement regimes. Two types of ground-based interceptors are envisioned for this purpose. One operates against the threat in the

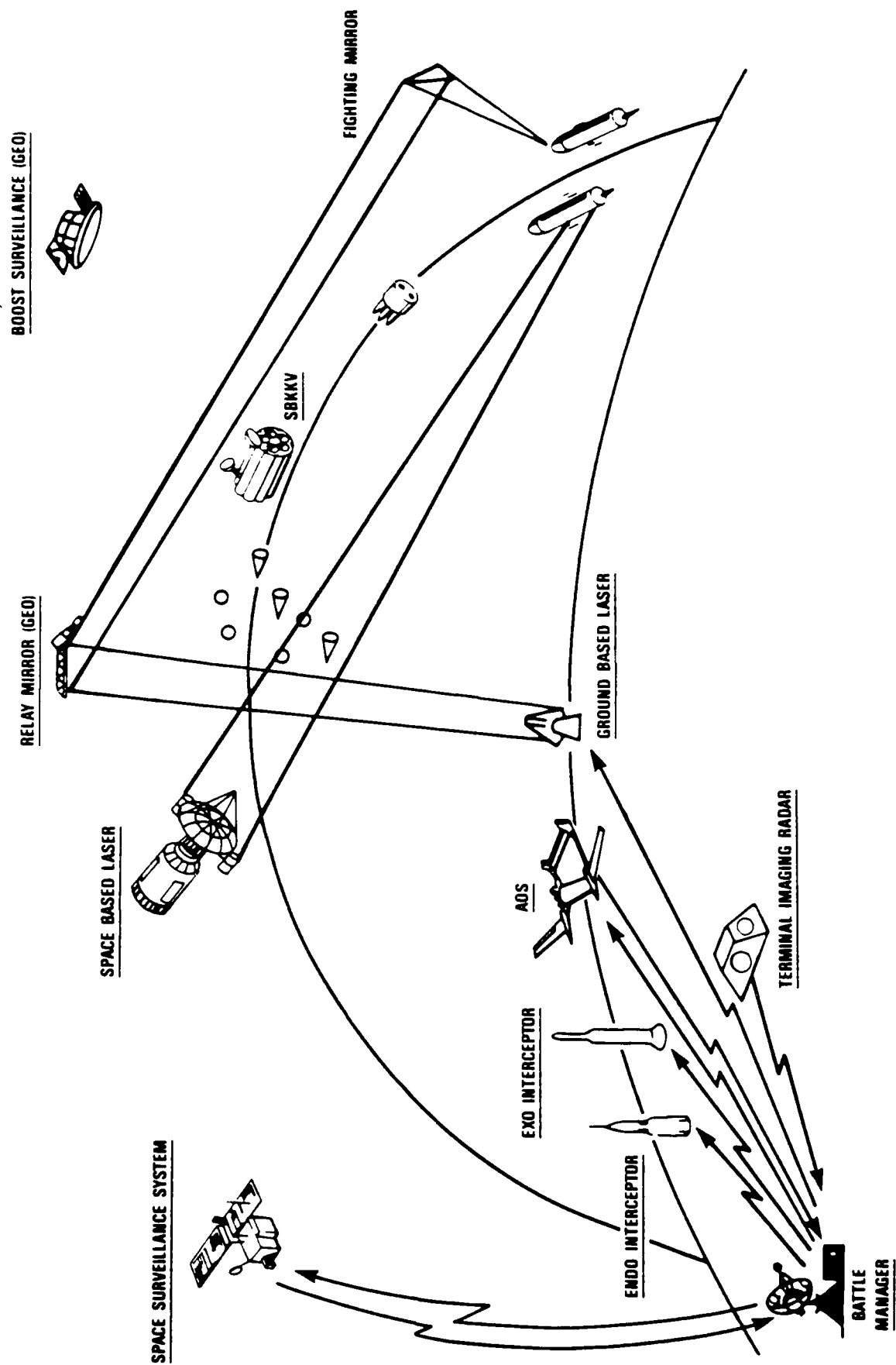
exoatmospheric and high-endoatmospheric regimes. The other operates in the mid- to lower endoatmospheric regime. Airborne sensor platforms are used in conjunction with this aspect of terminal defense.

As shown in Figure V.C.3, the boost-phase effectiveness of a near-term space-based kinetic-kill vehicle defense system may be augmented by adding directed energy weapons to the architectures. These are necessary in offensive responses when the engagement time available during the boost phase is reduced. Among directed energy weapons, some high-energy lasers are able to counter threats before they reach space, thereby increasing engagement time. Two alternatives are shown: a space-based laser and a ground-based laser using space-based relay and fighting mirrors. In either alternative, the number of space-based elements is likely to be small since these directed energy weapons have very high kill rates. This offers the offense an option to concentrate an attack on these assets in an effort to destroy the boost-phase defense capability of the system. Using a combination of kinetic and directed energy weapons against the offense offers a strong deterrent. To destroy this defense, the offense must pay a prohibitively high price.

The lasers required to achieve boost and post-boost vehicle kill have substantially higher performance levels than the levels required for performing the midcourse discrimination function described previously.

#### Ground-Based Weapons Architecture

The second architecture class of interest is ground-based assets. It consists largely of midcourse and terminal kinetic energy weapons with a small number of surveillance satellites as shown in Figure V.C.4. The satellites are used to provide an early warning of offensive missiles detected in their boost



V-C-7

Figure V.C.3 An Example of a Nonnuclear Ground- and Space-Based Architecture (DEW)

phase. This class is being examined because it relies on active defense elements not deployed in space and could be effective in cases where the offense is limited.

The midcourse tier of this class employs high altitude probes to initiate exoatmospheric engagements at long range. The remaining components and terminal tier functions are similar to the first architecture class although they must be deployed in larger quantities to compensate for the large number of engagements needed in the absence of a boost-phase intercept capability.

Recent technological developments show that directed energy weapons devices may add performance growth potential to a ground-based architecture by adding a boost-phase intercept capability. The possibility also exists to build DEW devices of considerably increased brightness.

Pop-up DEW may assist in alleviating the midcourse problem through effective discrimination of penetration aids in their midcourse. Providing this level of assistance, this class could become a much more viable candidate in moderate threat levels.

Hypervelocity particles also have promise as part of a strategic defense in this class. Particles traveling at such velocities may be able to attack individual missiles in their boost and post-boost phases.

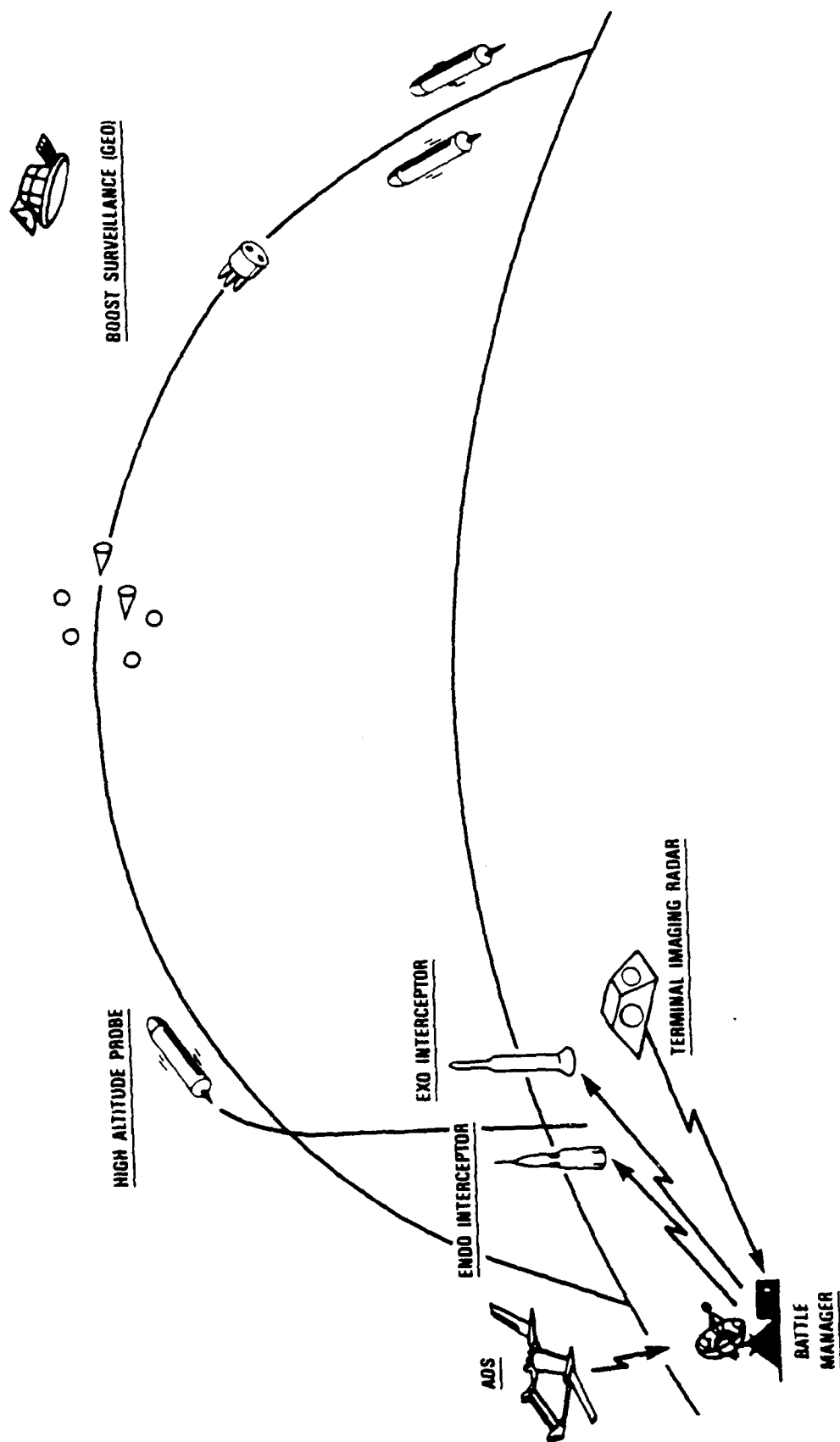


Figure V.C.4 Ground-Based KEW Architecture

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#### D. REGIONAL (THEATER) ARCHITECTURES

Architectures for regional (theater) defenses against ballistic missiles must take into account several factors which differentiate the regional from the strategic defense environment. For example, shorter-range ballistic missiles have reduced times of flight, lower trajectories, and greater warhead variety than ICBMs. They also have lower velocities and less throwweight. Other key differences include the different decision-making processes and the combined arms nature of the theater military environment.

NATO is now engaged in examining near-term counters to the growing Soviet tactical ballistic missile threat. While that effort is separate from the SDI, which has a longer-term focus, the SDIO expects that technologies and regional (theater) architectural concepts being pursued under the SDI Program can make an important contribution to the NATO program. The governments of the United Kingdom and Israel, as well as seven multinational contractor teams, are now conducting regional (theater) architecture studies under SDI research awards. These studies will address candidate architectures' resultant technology requirements, interfaces with existing defensive capabilities, and technology risks within current allied and American technology programs.

With their relatively longer flight times and extensive exoatmospheric flights, SS-20s and SS-12 Mod 2s would be vulnerable to space-based boost-phase defensive weapons. Since the shortest-range missiles never leave the atmosphere, they are not vulnerable to space-based interceptors. Nevertheless, short-range missiles have much lower velocities than intermediate-range and intercontinental ballistic missiles, making them vulnerable to other ground-based defensive weapons systems. These systems could be directed by airborne sensors throughout most of their flight.

The shorter times of flight of tactical ballistic missiles require fast acquisition, tracking, discrimination, and reaction which in turn requires greater sensor sensitivity and faster data processing. An added burden could be placed on the discrimination function if missiles with short flight times employed penetration aids. However, most shorter-range systems are single-warhead missiles which carry no decoys. An SDI contribution to a final regional defense could be similar to that shown in Figure V.D.1.

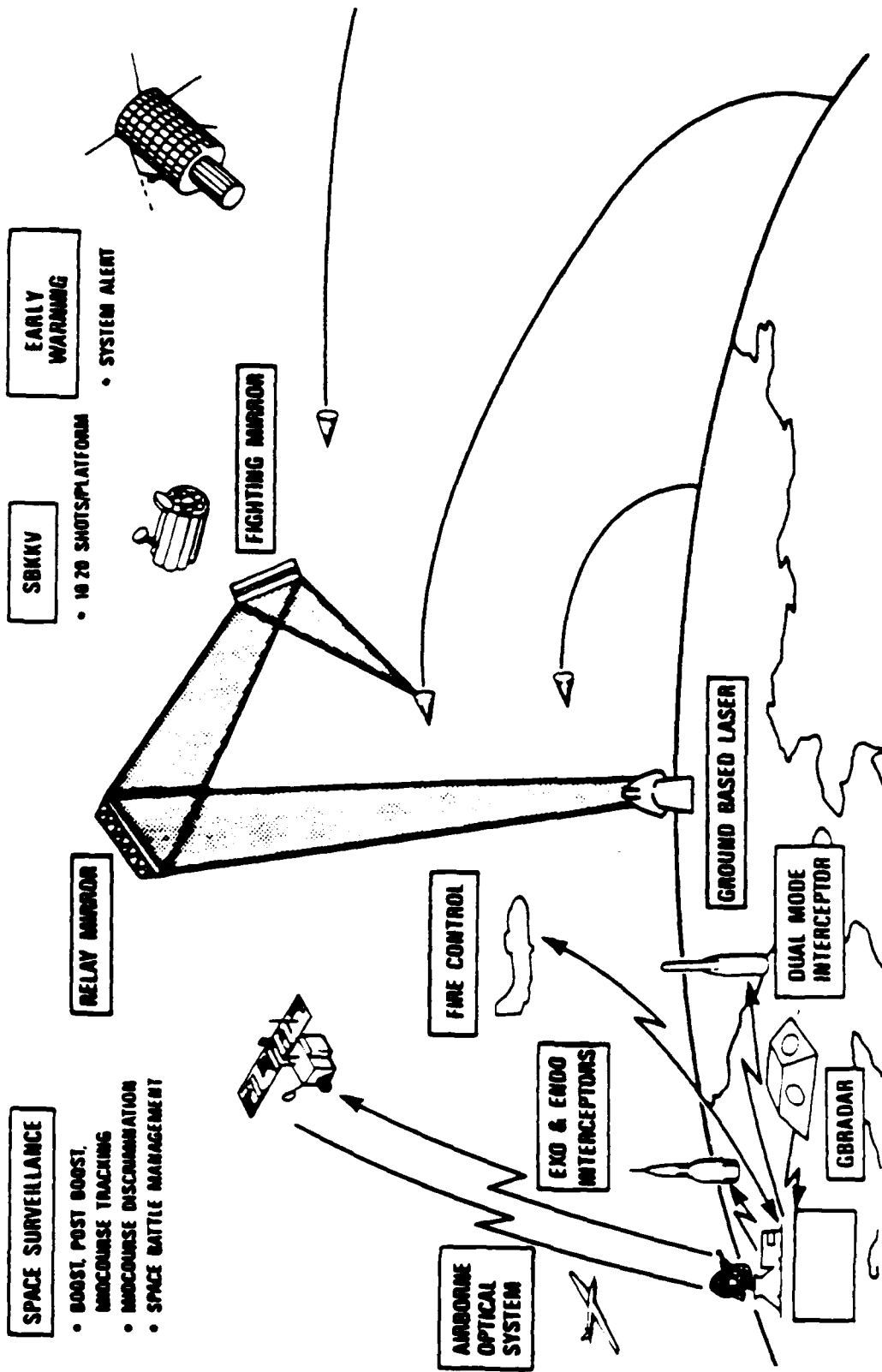


Figure V.D.1. Regional Defense Concept

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E. BATTLE MANAGEMENT/COMMAND, CONTROL, AND COMMUNICATIONS  
(BM/C<sup>3</sup>) PROGRAM

The Battle Management/Command, Control, and Communications Program develops and experimentally validates the architectures and technologies for a highly responsive, ultra-reliable, survivable, long-lived, and cost-effective BM/C<sup>3</sup> system. The BM/C<sup>3</sup> system must coordinate a complex, low-leakage, multitiered defense against ballistic missile attacks. It must operate reliably in a nuclear environment and while under direct enemy attack.

The BM/C<sup>3</sup> system associated with an effective multitiered defense presents significant technical challenges. Surveillance satellites, airborne sensors, and ground radars must locate targets and communicate track information to battle managers. The battle managers process the information and communicate target assignments to space- and ground-based weapons. Target assignments must be made so as to maximize the efficiency of the engagements. Surveillance and weapon elements provide information which must be evaluated for kill/damage assessment so targets may be re-engaged, if necessary. The activities and status of the space, air, and ground elements of the system must be monitored and controlled by well-defined command levels, ending with the National Command Authority (NCA). All of these functions must be performed with very high reliability in a nuclear environment while under direct enemy attack.

The BM/C<sup>3</sup> Program is structured into two projects, BM/C<sup>3</sup> Experimental Systems Project and BM/C<sup>3</sup> Technology Project. The Experimental Systems Project evaluates BM/C<sup>3</sup> concepts developed within system architectures and experimentally validates these concepts by developing experimental versions (EVs) to test the tactical configuration of the BM/C<sup>3</sup> system. The Technology Project develops the various technologies needed in the BM/C<sup>3</sup> system.

### BM/C<sup>3</sup> Experimental Systems Project

This project encompasses the two main tasks of BM/C<sup>3</sup> Architecture and BM/C<sup>3</sup> Experimental System Development. The first of these main tasks, Battle Management Architecture, performs the analysis, research and development, and design for the battle management and command, control, and communications subsystem for strategic defense. It establishes the resulting quantitative subsystem functional requirements, performs technology trade-offs, develops BM/C<sup>3</sup> operational concepts and specifications, and integrates the BM/C<sup>3</sup> requirements activity with the system architecture effort in the SDI Systems Analysis Project.

In addition to BM/C<sup>3</sup> operational concepts and system functionality, this task addresses how to achieve the battle management attributes of system security, system robustness and survivability, system tests, and system evolution. These attributes will play a key role in developing a strategic defense that can be realized.

BM/C<sup>3</sup> Experimental System Development is the second main task and concerns the analyses, research and development, and design leading to the definition and validation of experimental versions of the tactical configuration of the BM/C<sup>3</sup> system for strategic defense. This task defines the experimental version (EV), establishes the validity of the EV as a representation of the essential battle management technology, and develops the experimental version as a prototype of the battle management subsystem. The demonstration of the EVs is accomplished through a series of technology validation experiments that validate the various BM/C<sup>3</sup> technology issues.

### BM/C<sup>3</sup> System Architecture

Two generic classes of system architectures have been identified as a result of the system architecture studies. These classes are space-based systems and ground-based systems.

The spaced-based class of system architectures consists of systems whose effectiveness depends on space-deployed assets and normally include a ground-based terminal defense. The Air Force has lead Service responsibility for BM/C<sup>3</sup> architecture work supporting space-based systems.

The ground-based class of system architectures consists of systems whose effectiveness depends on terrestrially based assets but might include a space-deployed surveillance system and assets that "pop-up" or otherwise are transiently deployed in space in a survivable manner. Theater defense against ballistic missiles is viewed as a special case of the ground-based class of system architectures even though it may incorporate certain peculiarities not found in most strategic defense systems. The Army has lead Service responsibility for the ground-based systems class.

To ensure that the BM/C<sup>3</sup> architecture concepts are developed as an inherent part of a ballistic missile defense system, the BM/C<sup>3</sup> architecture studies have been integrated with the System Architecture project. Not only does this address criticisms identifying the lack of BM/C<sup>3</sup> architecture investigation by past system-level architecture studies, but it also requires more Service-level BM/C<sup>3</sup> architecture involvement in the system-level concepts. The complementary nature of Service architecture work will continue although at a reduced level of effort. The Services, however, are still encouraged to seek diversity in their architecture efforts.

Significant Accomplishments. Service BM/C<sup>3</sup> architecture activities have examined a number of promising BM/C<sup>3</sup> concepts, identified key technology drivers, and have shown that a number of technologies are common to a broad range of architectural concepts. Service activities have provided ranges of performance requirements to better support refining the BM/C<sup>3</sup> technology program. They have also provided a detailed analysis of

the implication on BM/C<sup>3</sup> of various functional allocation approaches.

A primary function of the BM/C<sup>3</sup> architecture task is to provide concept definitions for the BM/C<sup>3</sup> EVs. Accomplishments during the past year have been especially useful as the planning for the experimental versions have begun and the architecture studies have provided a baseline architecture for developing initial EVs. In conjunction with the concept definition effort, early versions of some models and simulations for various functional elements of potential strategic defense systems have been delivered. These models and simulations are key elements for validating a strategic defense system.

The FY 1987 program emphasizes moving beyond concept definition in BM/C<sup>3</sup> to a more detailed analysis of selected BM/C<sup>3</sup> implementations. The integrated System Architecture-BM/C<sup>3</sup> architecture studies will be used to accomplish this more detailed analysis. The Service BM/C<sup>3</sup> architecture work will focus on analyzing system-level architecture studies as well as supporting the development of their respective BM/C<sup>3</sup> experimental versions. It should be noted that a significant aspect of the FY 1987 effort will be to improve documentation and to require candidate system architectures to be defined in Ada Process Description Language (PDL). These efforts will help refine and direct the BM/C<sup>3</sup> technology program ensuring that the two BM/C<sup>3</sup> projects are linked.

Major Thrusts. The BM/C<sup>3</sup> architecture definition will continue to emphasize developing system requirements and system specifications in FY 1988. The models and simulations for various functional elements of candidate architectures will be refined and standardized in support of the experimental versions which will be evaluated in FY 1988. Future BM/C<sup>3</sup> architecture efforts will have increased rigor for defining and analyzing architecture concepts. The perception that BM/C<sup>3</sup> is too

complex to be realized and that BM/C<sup>3</sup> concepts are being approached as an applique to given configurations of weapons and sensors will be reduced.

#### BM/C<sup>3</sup> Experimental Systems Development

Three EVs have been identified and constitute subtasks under this project, these are the Ground-System, Space-System, and Communications Network experimental versions.

The Ground-System experimental version implements the BM/C<sup>3</sup> system for ground-based system architectures. This series of TVEs will eventually include hardware and software that will be evaluated through the National Test Bed in a system-wide, operational-like environment. EV development will evolve from simulations at the Advanced Research Center (ARC) of the U.S. Army Strategic Defense Command (SDC) and will incorporate the BM structures derived from the Army architecture work.

The Space System experimental version implements a BM/C<sup>3</sup> system for space-based system architectures. This experiment will be incrementally developed (through a series of TVEs) and will eventually include hardware and software that will be evaluated through the National Test Bed in a system-wide, operational-like environment. EV development will evolve from simulations developed at the Electronics Systems Division (ESD) at Air Force Systems Command (AFSC) and will incorporate the battle management structures derived from the Air Force architecture work.

The Communications Network experimental version implements an experimental communications network of the various battle management system constructs that will emerge from the two other EVs. The Communications Network EV is intended to evolve into a system that provides a faithful image of the communications network that will enable battle management of the defen-

sive systems. The Communications Network EV will be incrementally developed through a series of evolutions starting from an initial set of communication protocols and current communications network technology. Subsequent advanced capabilities for the Communications Network EV will incorporate advances in network control, security, operating systems, and other technologies that are being advanced to support the highly survivable, robust, and secure communications network necessary to support battle management for strategic defense. The Communications Network EV is the R&D aspect of the National Test Bed, and as this EV is built-up, it becomes an integral part of the NTB. Initially, the Communications Network EV will be largely a ground-based simulation, but will evolve into a system with space-based components. Because of the relation of this EV to the NTB and BM/C<sup>3</sup> for space-based systems, the Air Force will have ultimate responsibility for its development.

Significant Accomplishments. This past year, detailed planning began for the Ground-Based experimental version, which is labeled EV-88 and consists of a sequence of subexperiments to support geographical distribution as well as evolution to a prototype BM/C<sup>3</sup> system. The Ground-Based EV is a high priority as it will provide an assessment of early options for strategic defense and because much of the test bed capability needed to run the initial experiments exists at the Advanced Research Center at the U.S. Army SDC. The Spaced-Based experimental version will rely primarily on NTB resources not yet in place. However, several demonstrations using existing capabilities have been defined and will assess various battle management functional algorithms.

The FY 1987 program will consolidate and further refine plans for the EVs. Hardware and software to support the experiments will be purchased and will be integrated with the NTB program. Many simulations and models for candidate

strategic defense architectures and functional subelements will be delivered in 1987 and will form the baseline for near-term experiments which will demonstrate approaches related to ground-based SDI system architecture. Definition and initial implementation of an entry-level BM/C<sup>3</sup> experimental version for space-based SDI systems will commence. The initial Communications Network EV will be developed under the SDI Net project and result in a specification for the SDI Network Interface Processor Engine (i.e., the interface for a high-speed packet-switching network).

Major Thrusts. Initial space-based experiments will be in the final planning phase. Ground-based experiments will continue. The ground-based experiments will provide early validation of terrestrially based BM/C<sup>3</sup> system architecture and will also be the vehicle for integrating distributed test bed resources through the National Test Bed and initial implementation of the Communications EV.

#### BM/C<sup>3</sup> Technology Project

This project develops technologies required to support responsive, reliable, survivable BM/C<sup>3</sup> for strategic defense. Five technology tasks have been identified as follows:

- Battle management algorithms,
- C<sup>3</sup> network concepts,
- Processors,
- Communications, and
- Software engineering.

Under each technology task area, various subtasks are defined to resolve specific technology issues and develop alternative hardware/software prototypes or advances.

#### Battle Management Algorithms

Objectives. This task analyzes and researches the development of battle management algorithms responsive to the BM/C<sup>3</sup> architecture requirements developed in the BM/C<sup>3</sup> Experimental

Systems Project. Battle management algorithms are the mathematical/logical processes and procedures that perform resource allocation, manage and form the track file, execute command and control actions--be they autonomous or human-in-the-loop--and generally operate a strategic defense system in a robust manner that responds to change and evolving technology. Software implementation of battle management algorithms in a loosely coupled, widely dispersed, real-time, heterogeneous multiprocessor environment is an aspect of this task.

Direction. This project researches technology and develops a candidate set of algorithms. The work will rely heavily upon previous and ongoing algorithm work in distributed systems, decentralized control, and resource management (such as Navy battle group defense). Specific attention will be given to system-level algorithms peculiar to an SDI-layered defense and not addressed in other program elements. These algorithms are:

- Discrimination decision making, based on data collected by the system of sensors and the available intelligence data base;
- Weapon assignment algorithms accounting for multiple types of weapons in each tier, the presence of succeeding tiers, and system resource constraints;
- Discrimination sensor allocation during the midcourse, and particularly the terminal, phases;
- Kill assessment in all phases;
- System reconfiguration when weapon, surveillance, and/or BM/C<sup>3</sup> resources are damaged; and

- Defense selection when system elements are under attack.

Significant Accomplishments. The initial designs of the data fusion and discrimination algorithms were completed, and software design and coding of these algorithms has begun. Design work on the situation assessment and weapon allocation algorithms has commenced, and the design of a novel parallel track file Data Base Management System (DBMS) was completed. The discrimination system is being implemented as an expert system to investigate the performance enhancements offered by knowledge-based systems and artificial intelligence.

In FY 1987, work will concentrate on developing algorithms for real-time critical BM/C<sup>3</sup> functions. Adaption to multi-processor architectures will be paramount.

Major Thrusts. Experimental versions of selected battle management algorithms will be used in candidate processor architectures. These will be evaluated in the Experimental Systems Project against real and simulated threats.

#### Network Concepts

Objectives. This task analyzes and researches the development of BM/C<sup>3</sup> networks responsive to the architecture requirements developed in the BM/C<sup>3</sup> Experimental Systems Project. C<sup>3</sup> network concepts are the mathematical/logical processes and procedures that control and manage the C<sup>3</sup> network and its assets of processors and communications links to provide the high-performance, fault-tolerant, secure, and survivable C<sup>3</sup> network environment within which the battle management algorithms function.

Direction. This project will specify, design, develop, verify, and validate alternative BM/C<sup>3</sup> network concepts. Software implementation of C<sup>3</sup> network concepts in a loosely

coupled, widely dispersed, real-time heterogeneous multiprocessor environment supported by multi-mode/multi-media communications is part of this task.

Significant Accomplishments. Protocols have been developed for an inter-netted communications system to support distributed simulation of SDI BM/C<sup>3</sup> and other system elements. Alternative candidate network configurations are being analyzed. An initial design of a candidate network control algorithm has been completed and software coding has begun.

Developments in distributed, decentralized operating systems for heterogeneous multiprocessors are being pursued in FY 1987. Work also addresses concepts for distributed, real-time data bases. Concepts for protocols and control of distributed information processing networks are being addressed.

Major Thrusts. Several alternative networking approaches will be developed and implemented in emulations of operating systems. A trusted distributed operating system will be developed.

#### Processors

Objectives. This task develops the information processing technology, devices, and subsystems which are secure; exhibit high performance; and are fault tolerant, space qualified, and hardened to withstand hostile environments. This task also includes developing operating systems, executive and file management software, and firmware that is indigenous to the local processing environment.

Direction. This task will develop the critical circuit and system technologies and architectures required for high-performance, fault-tolerant processing. Results from hardened microelectronics, high-performance parallel processor and fault-tolerant technologies will be combined to meet critical SDI processor requirements.

Significant Accomplishments. Technology approaches were developed to provide alternatives for developing and evaluating fault-tolerant processor concepts, technologies, and designs. Circuit technologies which can withstand both high radiation doses and single-event upsets have been pursued.

Building on work performed under the Defense Advanced Research Project Agency's (DARPA's) strategic computing program and at the National Aeronautics and Space Administration's (NASA's) Jet Propulsion Lab, near-term experiments are planned in FY 1987 to assess different high-performance, fault-tolerant multiprocessor implementation concepts. Work on high-performance, fault-tolerant multiprocessors will address both shared memory and ensemble architecture classes as well as hybrid schemes using systolic array accelerators. Approaches for real-time software implementations of battle management functions on multiprocessor computers are being pursued.

Major Thrusts. Critical circuit technology development will continue. Results of the efforts in hardened microelectronics and fault-tolerant computing will be combined with research on high-performance architectures. High-performance, fault-tolerant machines will be built and their performance verified.

#### Communications and Software Engineering

Objectives. This task develops the communications technology, devices, and subsystems that are secure and robust and support multi-mode/multi-media mission required data rates for several alternative defensive architectures and their variations. This task also includes developing embedded software and firmware that is indigenous to the communications environment.

Direction. This project will pursue communications system planning and design, communications protocols, candidate

communications network architectures, critical communications technologies, and demonstration of survivable dynamic communications networks.

Significant Accomplishments. Hardware requirements were formulated and analyzed for the wide-band and narrow-band links needed to support the inter-netted communications system. Work was pursued on component technology needed to support 60 GHz radio frequency (RF) and laser communications links.

In FY 1987, work on the required component technology will be continued. Designs of RF and laser communications links for both space-to-space and space-to-ground links will be pursued.

Major Thrusts. Proof-of-concept hardware and software will be developed for RF and laser links to provide highly reliable, secure, robust, and survivable communications.

#### Software Engineering

Objectives. This task performs the analysis, evaluation, and research leading to the creation of secure SDI software development environments which provide the capability to produce software with the requisite productivity and quality. It is required that there be a near-term capability to support the BM/C<sup>3</sup> experimental systems project (though this may be provided by the industrial sector) and a capability to support a defensive system deployment, if such a direction is chosen.

Direction. This task will upgrade, tailor, and expand existing software development activities to the maximum extent possible to meet SDI needs. This task includes developing methodologies, techniques, and strategies to provide reliable BM/C<sup>3</sup> software that adapts to the evolving requirements of strategic defense and provides the trustworthiness associated

with a secure system. It also supports the development and automation of tools and techniques, methodologies, and philosophies for organizing the requirements, design, and code-level implementation of BM/C<sup>3</sup> software.

Significant Accomplishments. Alternative software development technologies were analyzed and approaches were selected for application to support research efforts. Concepts for an advanced software development environment were developed. Software verification and validation approaches were analyzed.

Work toward completing a Distributed Computer Design System (DCDS) software engineering environment for Ada is the thrust of FY 1987's efforts. Work will continue on an Ada-based Process Description Language. This PDL will become the standard for process descriptions within SDI BM/C<sup>3</sup> and help ensure compatibility of architecture descriptions, algorithms, and software. Development of the next-generation of object-based software engineering environment for large-scale multiprocessor-based systems is being supported.

Major Thrusts. The prototype parallel software environment will be delivered in FY 1988. In the following years a large-scale multiprocessor software environment for secure software development will be completed and an acquisition strategy for a software development for system deployment will be defined.

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## F. NATIONAL TEST BED (NTB)

### Objective

The NTB Program will compare, evaluate, and test the alternative architecture definitions for an end-to-end layered strategic defense and its associated BM/C<sup>3</sup> as well as evaluate specific technology applications in a system framework defined by these architecture alternatives. The NTB will consist of a number of geographically separated experiment and simulation facilities that will be electronically linked to simulate a layered ballistic missile defense system. At the center of these facilities will be the National Test Facility (NTF) that will serve as the central control and coordinating point for the NTB. It will also be the major simulation activity for the SDI Program and develop and execute large-scale distributed simulations of the system providing as much operational realism as possible within the constraints of international agreements and funding. As an integrated set of resources, the NTB will be a single national resource dedicated to the SDI for addressing the many critical issues necessary to support an informed decision on future development and deployment of strategic defense against ballistic missiles.

### Description

The NTB Program is executed through a Joint Program Office (NTB JPO) reporting to both the U.S. Air Force Electronic Systems Division (ESD) and the SDIO. This NTB JPO is responsible for the definition, development, and operation of the NTB. This includes primarily the design and development of the NTF and the communications network and interfaces that link the NTB into an integrated whole. It is the SDIO's intention to ensure NTF access to the U.S. Space Command and seek its participation in the definition of the operational concepts for a strategic defense. This will be done using the NTB's large-scale simulation capability. Figure V.F.1 shows a concept for establishing the NTB.

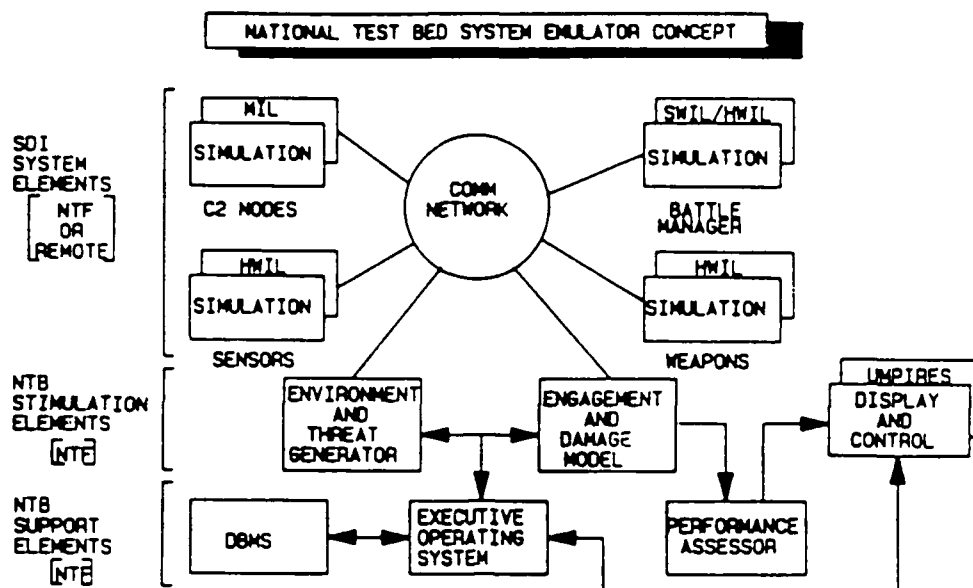


Figure V.F.1 National Test Bed System Emulator Concept

The NTF will house the support elements and the simulation elements. The support elements provide for the collection and analysis of the simulation results as well as the control of the simulations. The simulation elements create a realistic simulated threat in sufficient numbers to gain confidence that the critical information and data networks can function correctly and provide the necessary decision information to the various command and control nodes and battle managers. The NTF will also serve as the network controller for the computer communications network that links the NTF with the distributed activities of NTB. The communications network will consist of local-area networks and long-distance communications links for the interconnection of simulations and experiments of the elements of strategic defense. Figure V.F.2 shows some of the distributed elements of the NTB and its relationship to the NTF.

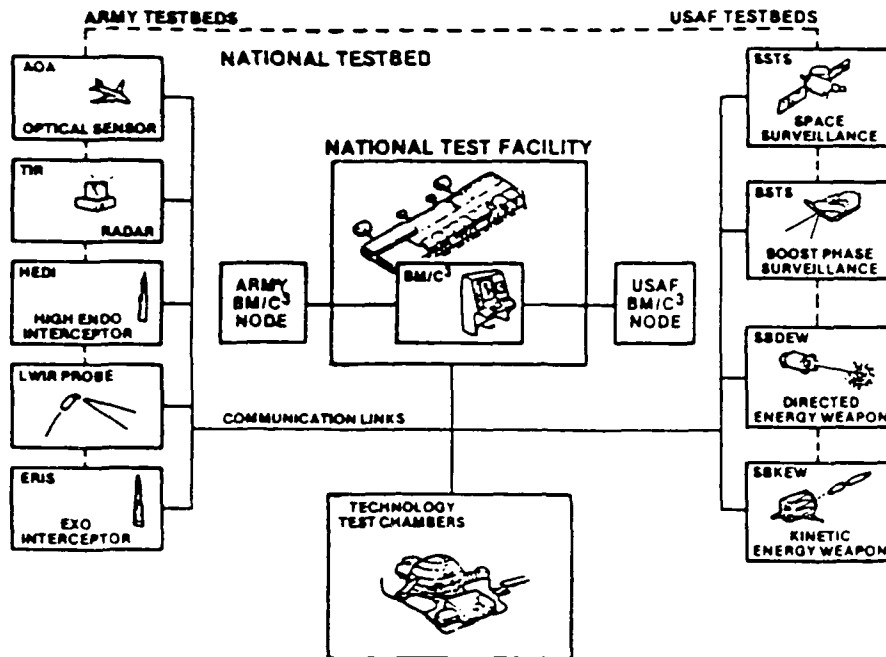


Figure V.F.2 Elements of the NTB and Their Relationship to the NTF

### Accomplishments

During the past year significant progress has been made toward further defining the NTB. A formal management team has been established in a JPO at ESD. A series of "horse race" contracts were awarded in March 1986 to conduct a detailed concept definition and preliminary design study. In July 1986, two contractors, Martin Marietta and Rockwell International, were selected to complete the preliminary concept designs. A product of their efforts will be a simulation of the NTB to aid the JPO in test planning and in determining NTB architecture requirements. A thorough site selection process is nearing completion and it is planned that interim NTF capabilities will be ready for demonstration in 1988. Additional capability will be added incrementally to support BM/C<sup>3</sup> analyses, high-fidelity simulations, hardware-in-the-loop experiments, TVEs, and man-in-the-loop experiments.

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#### G. SYSTEMS ENGINEERING

The Systems Engineering Directorate performs functions essential to the SDI Program by assuring comprehensive preparation for the development, production, and deployment/operations phases of an SDI system. System engineering disciplines are applied program-wide within individual program elements. In addition, these disciplines must be applied in a uniform and interactive way to link the diverse programs which comprise a total SDI capability. Major disciplines include engineering analysis, supportability and logistics integration, and systems integration. The Systems Engineering Directorate performs these functions and advocates their consistent application by others in the Program, assuring that an SDI system will be fully integrated, capable, sustainable throughout its life cycle, and affordable. A decision to move from the technology validation phase of the program to a phased development depends upon a thorough systems engineering analysis.

##### Engineering Analysis

Detailed analysis is required for individual elements of the SDI Program. These analyses may be focused on the systematic breakdown of systems into multiple layers of requirements (system requirements analysis). They may also be oriented toward program affordability, system or component costs, producibility of systems, technical interfaces, or other analytical issues that might otherwise be missed when analysis is performed from a total system standpoint.

Cost Research and Analysis. Comprehensive cost research and cost analysis is being performed to provide full cost understanding and credibility for SDI program planning and to adequately support an SDI decision on full-scale engineering development. Specific goals are to develop cost data bases and cost estimating techniques to accurately estimate life-cycle costs of architectures and component systems, establish design-to-cost goals, support architecture assessment, and

conduct research in ways to reduce costs in the SDI Program.

Current efforts are focused on methodologies for analyzing the cost-effectiveness of various architectures standardization in an SDI work breakdown structure, refinement of cost-estimating relationships (CERs) which are pertinent for SDI systems, and development of achievable cost goals for selected component systems. In developing cost goals, a primary thrust is the identification of feasible opportunities to reduce SDI costs below today's levels through technology development and the application of advanced manufacturing methods.

Industrial Base and Producibility Analysis. Future industrial requirements to support developing an SDI system will be significant. The SDI Program must identify strategies that will provide the full range of required capabilities. Technologies now being developed by the SDIO have significant industrial implications such as the need for expanded capacity, automated manufacturing techniques, and advanced materials. The size of the Program may require industry to maintain unprecedented production rates for many components and systems. Proper attention to industrial base and producibility issues will reduce costs and result in a cost-effective program. The SDI will have massive system integration requirements that industry must meet. Current efforts are oriented toward analysis of industrial base and producibility requirements posed by system architecture studies and assessment of the risks involved. These studies will be used in targeting research to resolve potential producibility problems and to determine needed manufacturing technologies before systems enter production.

Requirements Analysis. SDI system functional requirements generated by architecture studies must be synthesized by means of functional or systems performance analysis. This is

necessary to optimize functions and generate more detailed system requirements leading to the design process. A good system design reflects an optimum balance among performance, support, and economic factors which is attained through a systematic and comprehensive trade-off and analysis effort accomplished early in system development. These results will support engineering decisions on system production, operations and support, and will have a significant impact on SDI effectiveness and cost.

#### Logistics Integration

Any postulated SDI capability must be supportable and sustainable at an affordable cost throughout its life cycle. Issues involved with making this happen must be addressed early in conceptual development, prior to or coincidental with major system concept/design decisions. The SDI Program is addressing these issues now.

Supportability and Logistics Integration. Systems-level supportability and logistics integration is the responsibility of the Logistics Integration Division of the Systems Engineering Directorate. Supportability issues must be addressed for both hardware and software system design as well as issues associated with ground-, air-, and space-based system operating environments and their related constraints. A key element is ensuring that the SDIO Supportability Research Policy (signed by the SDIO Director on 15 October 1985) is aggressively applied by all Program Elements.

Research and analyses will be conducted to determine the appropriate levels of standardization, reliability, maintainability, and availability at the systems level. In addition, transportation and transportability and evolutionary upgrade requirements will be addressed, as well as the impact of affordability constraints on potential operations and support scenarios. A major systems-level Logistics Support Analysis

(LSA) effort was initiated in September 1986. This contract will produce a tailored SDI LSA strategy and plan for the long term and will identify and evaluate alternative support system concepts. Trade-off studies will be conducted iteratively, and the impact of these studies will be evaluated with respect to alternative technology solutions and system architectures. Currently available and required logistics technologies will be evaluated. Investment plans will be developed and prioritized to ensure that appropriate support resources and lead times are identified. Early program and design reviews will be conducted to identify early in the design process pertinent support factors related to design considerations and the intended use of the proposed system.

An Integrated Support Working Group (ISWG) has been formed to permit a thorough integration of the supportability concerns of the SDI Program across the diverse organizational elements of which it is comprised. The ISWG structure includes periodic general meetings and working panels covering details of support issues in such areas as maintainability, logistics modeling and simulation, architecture and support analysis, logistics technologies, and basing and environment.

The ultimate goal of logistics integration is to ensure that any SDI architecture or system chosen for further development will be supportable and will achieve system readiness and effectiveness goals at the minimum possible life-cycle cost.

Basing, Deployment, and Environmental Impact Analysis. The architecture studies have developed different potential configurations for the elements of ground-based systems and for systems that have a substantial number of ground-based elements. The siting of large experimental facilities for technology verification also requires careful coordination and consideration.

Selecting sites and ground facilities requires close discussion and cooperation within the Defense Department and with other federal, state, and local agencies. Large land areas are required for ballistic missile defense research and development activities. There are also some implications for existing DoD activities that must be addressed. Analysis of available government facilities is required, and the impact of using these facilities must be fully assessed. An equally substantial issue coupled to the site selection question is determining the concept for support bases and where supporting systems would be based. This will include personnel housing, socioeconomic issues, and concerns of the host military and civilian communities.

When siting and support basing discussions have been initially reviewed, the entire proposal will be reviewed as required by provisions of the National Environmental Policy Act and other environmental protection legislation. The SDIO is now drafting policy for complete and efficient environment analysis of proposed actions and alternatives that is responsive to both the mission and the public. The SDIO, through the Basing and Environmental Impacts Panel of the ISWG, is coordinating the potential siting and basing issues and environmental analysis. Outside of the panel structure, the military departments, other agencies, and other interested entities are continuously coordinating potential siting and basing issues.

The SDIO, via the Basing and Environmental Impacts Panel and the Logistics Technology Panel, is searching for technology developments that will streamline the preparation of site selection studies, supporting base studies, and the environmental impact analysis process. Through synergistic and iterative review of the progress in all three areas, the SDIO moves toward its objective of technically optimum sites which have

the least cost for development and the least impact on the human environment.

### Systems Integration

Systems integration is a key element of systems engineering which must be applied on an individual program basis throughout the various program levels of the SDI. Integration across the diverse system elements must be assured by a central organization which possesses a macro-view of the entire system. This is done by the Systems Integration Division. The objective of systems integration is to assure the synthesis of individual SDI system elements into an optimum system which adequately balances performance, cost, and reliability.

Interface Analysis. The identification and management of system and subsystem interfaces is required as a primary step in the integration of any SDI capability. Once identified, these interfaces will be defined in detail. An SDI system will be postulated according to a given architecture using the various subsystems and the interfaces that connect those subsystems. Issues will be generated from this construction and iterated as required. It is these issues that will be fed back to those responsible for defining interfaces so as to ensure a successful integration of the subsystems into an effective SDI system.

Technology Assessment. A responsibility of Systems Engineering is to constantly identify technologies under research and development and recommend technology investments having high potential. A currently proposed study will assess each technology under development or consideration and evaluate that technology with regard to risk of the investment, the architectural concepts to which it applies, and any overlap in function or capability that particular technology may have with other technologies. Another proposed activity will place

each technology development activity on a development plan from the present through full-scale engineering development and beyond.

Experiments. Systems integration is planning to conduct its first integration experiment, Near-Term System Integration Test and Evaluation (NSITE). This planned sensor experiment is directed toward the resolution of integration issues involving discrimination utilizing passive and active sensors as well as a neutral particle beam source. The purpose of the experiment is to obtain data on handoffs between systems in real time utilizing a local battle manager concept and preliminary SDI communications systems.

Macro-Systems Integration and Program Management. The SDIO must control and direct a single system-wide integration activity to focus these efforts. A plan and numerous activities are required to successfully implement these concepts. A Systems Engineering Management Plan (SEMP) is under development in 1987 with each subsystem being networked and critical paths established. An executive-level statement of work for the integration task is being prepared. An assessment of all known issues relating to systems integration, along with each scheduled resolution, is being performed. Criteria and requirements for a Milestone II FSED decision are being developed, and, within the SEMP, a schedule is being developed to satisfy these requirements.

The systems integration function brings together, correlates, and makes more effective the capabilities of the various programs and technology offices. It is acknowledged by the SDIO that full integration of such capabilities is required as the program matures and moves toward decision. The integration effort has just begun and will undergo significant evolution and adjustments during 1987.

#### H. TECHNOLOGY REQUIREMENTS

The SDI Technology Requirements Directorate is responsible for determining and communicating technology requirements for guiding the formulation of the technology portions of the SDI Program.

##### Requirements Identification

This activity assures the technology requirements process involves the full and active participation of the Technology Deputate and all appropriate external technology organizations. This is accomplished through the initiation of formal and informal interactions with the technologists to communicate the system performance and technology needs emerging from the system architectures and to assist the Technology Deputate in focusing its programs to support the evolving SDI development and deployment strategies. Feedback on technology progress is provided by the directorate to the system architectures and system engineers to ensure their full awareness of these vital inputs to the SDI systems analysis and integration programs.

##### Technical Issue Analysis

Major technical issues identified in the system architectures and special studies are analyzed to determine their significance to the SDI mission goals. Emphasis is on the assessment of technical feasibility issues and the implications of new and emerging technologies to the SDI system architectures.

##### Requirements Reporting

This activity provides for the periodic reporting of technology requirements to assure their full dissemination. Official requirements documents are issued with wide distribution, including participating allies, consistent with security regulations. Briefings are conducted, including those involving industrial forums, to augment the documentation of requirements information.

## CHAPTER VI

### TECHNOLOGY PERSPECTIVE

#### A. INTRODUCTION

Four years have passed since President Reagan announced his defense initiative calling for an intensive and comprehensive effort to define a long-term program. His confidence that it was time to pursue such a program was based on two major assumptions: first, technology had reached a point that showed great promise, and, second, the nation had the technological potential to bring the promise to reality.

Building upon the foundation provided by the Fletcher Study, a broad-based, aggressive, and sound technical program was defined and put into action. Technical efforts were aggregated into Program Elements, with each element examining a specified portion of a crucial SDI technology. As discussed in the preceding chapter, one of the Program Elements, SA/BM, consists of studies and analyses of systems, architectures, and performance requirements as well as technology development for C<sup>3</sup>. This chapter describes the more technical Program Elements under the direction of the Deputy for Technology and the progress that has been made to date in each of them. A discussion of the objectives for FY 1988 and plans for the future including major milestones is also included.

Recognizing the importance of innovation, the SDIO has also organized an activity in an office reporting to the Deputy for Technology to promote innovative ideas. A fixed fraction of each Program Element is set aside to fund promising innovative concepts. This work is characterized by high-risk, high-payoff, low-cost research that can be performed by skilled professionals anywhere (laboratories, small businesses, industry, universities). The work involves mostly unclassified fundamental research, and its results, once evaluated, will help create new opportunities for all the other Program Elements.

The technical program is organized to support future decisions on defensive options. To do this, diverse efforts producing essential answers to critical issues must converge. Among the important critical issues requiring resolution before a decision on development can be made are:

- The need for "smart" high-speed kinetic-kill projectiles. This type of projectile will help assure the viability of a kinetic energy alternative for boost-phase kill.
- Reliable discrimination for exoatmospheric interceptors.
- Hypervelocity, repetitively pulsed rail guns with "smart" bullets.
- Active discrimination using radar and/or laser radar (LADAR) and interactive discriminators using lasers and neutral particle beams.
- Hardening of passive sensors to hostile environments.
- Booster "hard body" identification in the presence of the rocket's "plume."
- High brightness lasers, particle beams, and nuclear-driven technology for boost-phase intercept against "responsive" threats.
- Survivability and countermeasures work.
- Lethality experiments carried out at levels characteristic of realistic weapons on realistic targets.
- Space-based power supplies and power conditioning equipment.

- Reduction in space transportation costs.

The various accomplishments each Program Element has made in the past years show that research has answered a number of unresolved issues.

Typically, as a given technology matures, new questions arise as old ones are answered. Sometimes the more mature technologies appear less promising than other less well-researched technologies that have not, as yet, encountered the tougher questions. Care has to be taken to avoid being overly critical of concepts well along in research or to expect too much from concepts not yet put to the test. The SDI Program described in the following sections is designed to develop emerging technologies logically and on a timely basis so as to provide a better basis for a credible deterrence.

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B. SURVEILLANCE, ACQUISITION, TRACKING, AND KILL ASSESSMENT  
(SATKA) PROGRAM  
Technical Objectives

The SATKA Program provides the research efforts to identify and validate the various sensor concepts for performing surveillance, acquisition, tracking, discrimination, and kill assessment of enemy ballistic missiles from launch to warhead reentry and detonation (birth-to-death). The program is divided into three project areas: technology base development, data collection and measurements, and technology integration experiments. The technology development program is structured to quantify the risk and cost of achieving a reliable and survivable system for a multitiered SDI. It encompasses IR sensors, laser radars, microwave radars, interactive discrimination, and signal processing. Data collection and measurement projects provide the facilities, measurement equipment, and test targets for the collection and interpretation of signature data on ballistic missile components, reentry vehicles, and backgrounds. The technology integration experiments planned for this program test a broad range of technologies to support the SATKA function and encompass three basic sensor suites. These are:

- Boost-phase sensors which detect the hot rocket exhaust, provide an attack alert, and give the initial tracking data to the boost-phase interceptors. They also provide data to assist in kill assessment.
- Midcourse surveillance and discrimination sensors which track the post-boost vehicles, reentry vehicles, decoys, chaff, and other debris, discriminate between the reentry vehicles carrying warheads and decoys; provide target position data required to bring the midcourse intercept weapons to bear; and assist in kill assessment.

- Terminal-phase surveillance which acquires, tracks, and collects data on the behavior of objects reentering the atmosphere to support discrimination, predict intercept points, and assess kills.

The Boost Surveillance and Tracking System (BSTS) Experiment concentrates on the requirement for a fully responsive space-based system to detect ballistic missiles in the boost phase. The BSTS (artist's concept shown in Figure VI.B.1) provides attack warning and assessment information, and generates track files for the National Command Authority and battle managers. The technologies being explored for this program include better sensors, survivability, and manufacturing technologies.

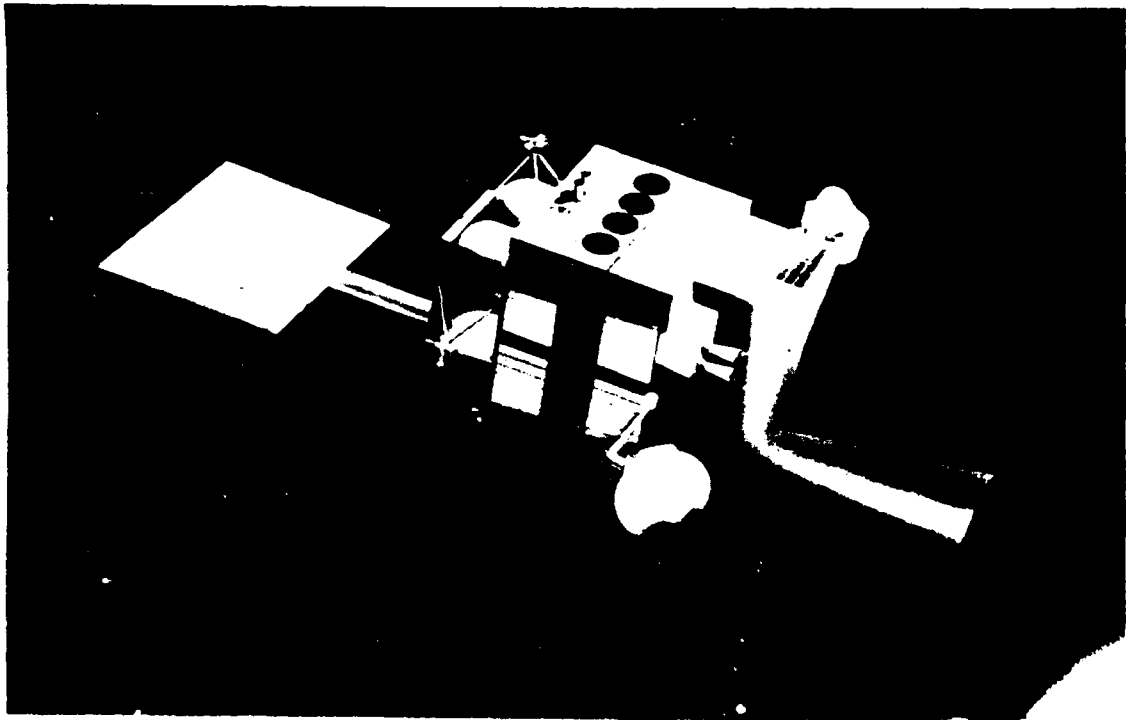


Figure VI.B.1. Boost Surveillance and Tracking System

In the post-boost and midcourse phases, sensors must provide accurate and efficient tracking as well as discrimination between reentry vehicles (RVs), lightweight penetration aids, and space debris. Midcourse surveillance systems must be capable of accepting track files from boost-phase surveillance systems and must provide track data for handoff to post-boost and midcourse interceptors as well as terminal-phase tracking systems. The Space Surveillance and Tracking System (SSTS) would provide a near real-time, fully responsive space-based system for midcourse ballistic missile surveillance and tracking as well as timely satellite attack warning and verification. The SSTS experiment (artist's concept shown in Figure VI.B.2) provides concept definition and preliminary research in the form of integrated ground demonstrations and a space-based surveillance and tracking experiment. This program will provide the data base to determine concept feasibility and effectiveness.

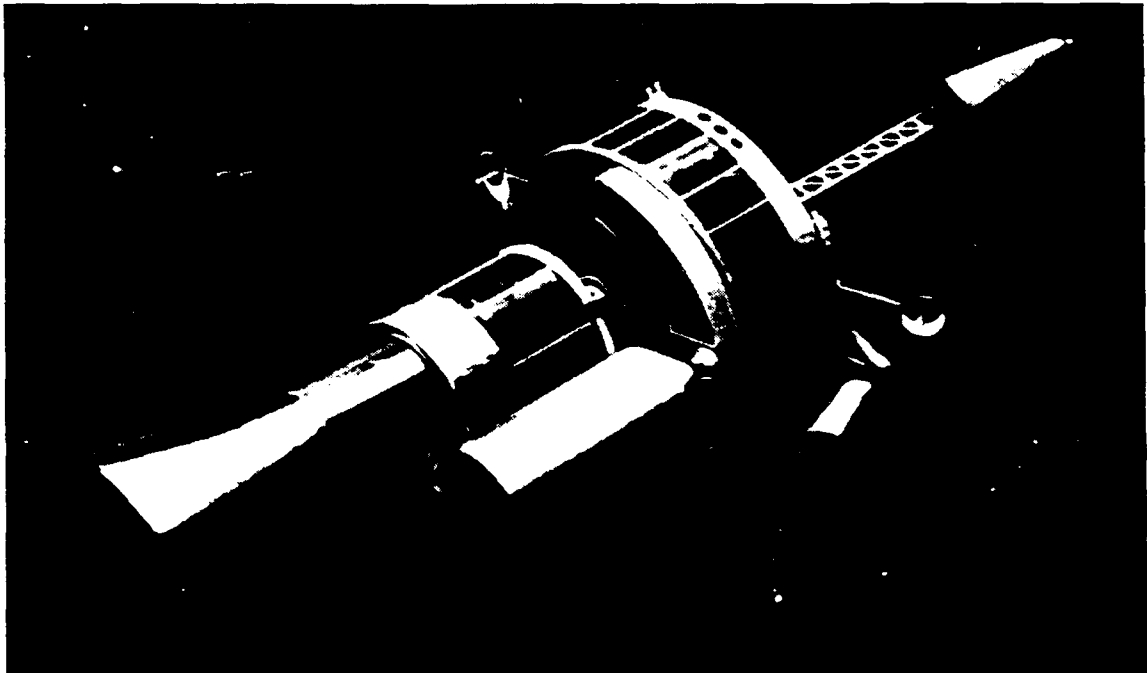


Figure VI.B.2. Space Surveillance and Tracking System

The SSTS is complemented by the LWIR probe which would support the midcourse phase and early terminal defense. An artist's concept of the LWIR probe, presently in the concept definition phase, is shown in Figure VI.B.3.

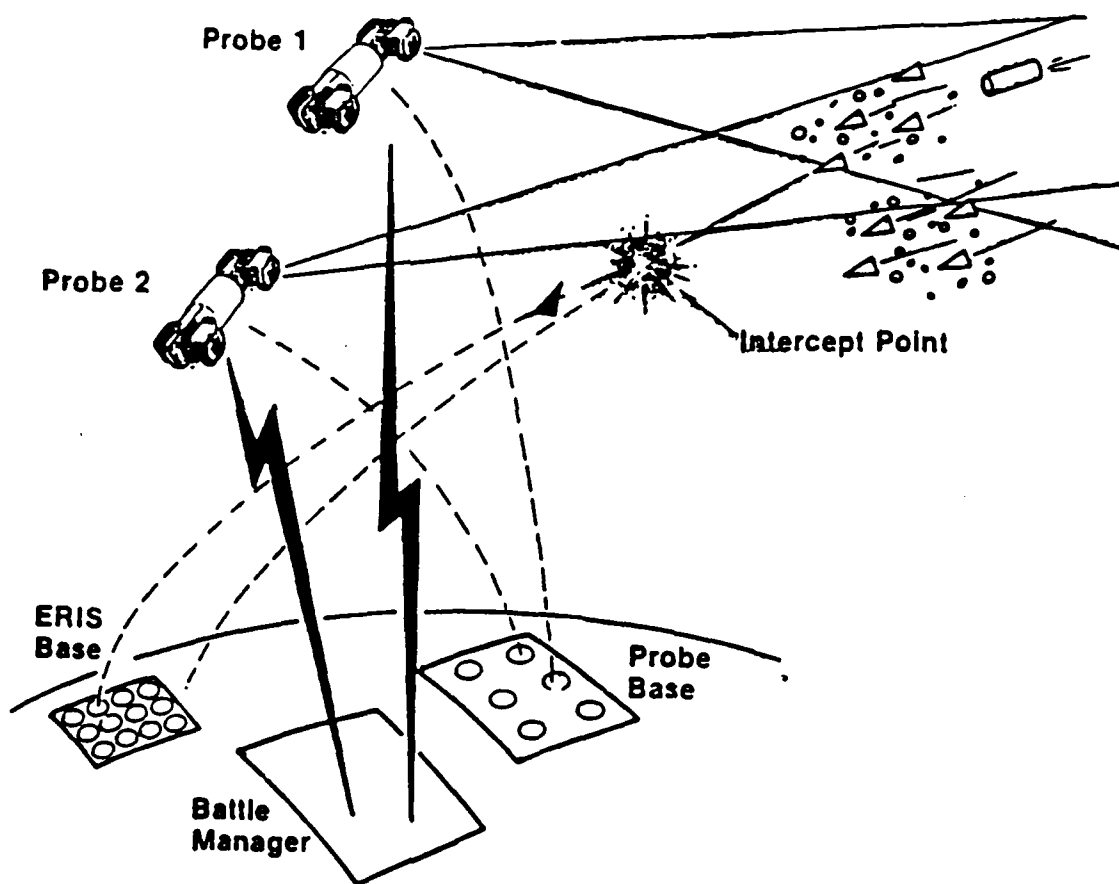


Figure VI.B.3 LWIR Probe

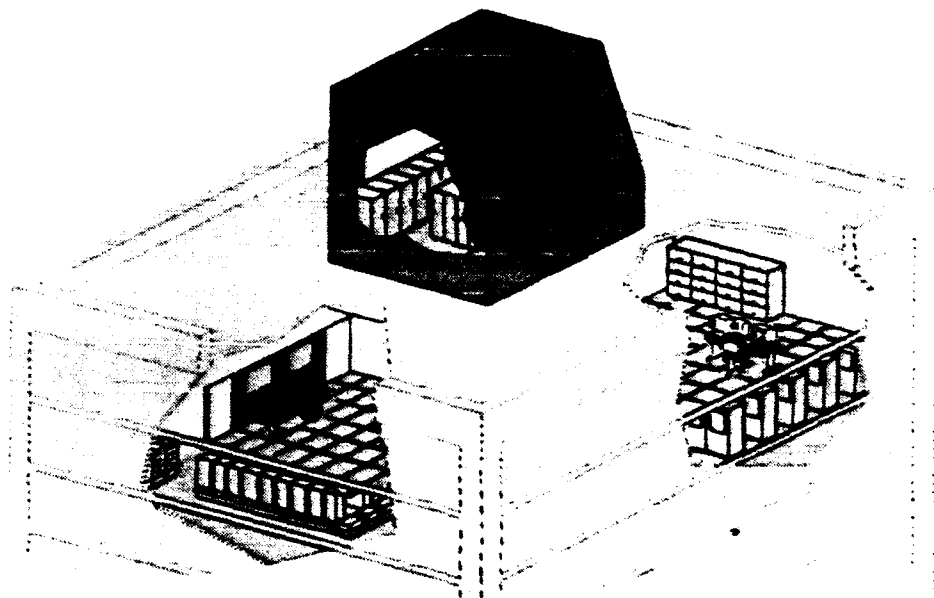
Terminal-phase sensors must provide efficient tracking and discrimination of RVs from penetration aids and other debris based on radiometric and ballistic information. Systems must be capable of receiving track information from midcourse sensors, tracking the target, processing the data, and passing commands to intercept vehicles.

The Airborne Optical Surveillance (AOS) concept is shown in Figure VI.B.4. It is an aircraft-based, late-midcourse and terminal-phase acquisition, tracking and discrimination system capable of handoff to a ground-based surveillance system for terminal intercept. This sensor system would have the wide field-of-view and high resolution essential for late-midcourse and terminal-phase detection, discrimination, and designation of ballistic missile reentry vehicles. The technology requirements for the AOS will be defined during the concept definition phase currently under way.



Figure VI.B.4 Airborne Optical Surveillance Concept

The ground-based radar will receive handover data from the Airborne Optical Surveillance system and then provide precise track information for high endoatmospheric terminal-phase engagements of the most threatening objects. The system would also provide kill assessment and retargeting capability over a large area of terminal-phase engagement. It is depicted in Figure VI.B.5.



## **TERMINAL IMAGING RADAR**

Figure VI.B.5. Terminal Imaging Radar

### Significant Accomplishments

The technology development supported by the sensors program contributes to the attainment of the overall SATKA objectives. Over the past year, sensor technology developments continued vigorously in five generic areas. These areas are radar technology, IR sensors, laser radars, interactive discrimination, and signal processing.

Radar component development included production of initial quantities of high-power transmit/receive modules for use in reliability and radiation hardness testing essential to the survival of the SATKA element in the nuclear environment. Preliminary design for the Terminal Imaging Radar (TIR) was completed, and a detailed design effort was initiated upon validation of the two competing preliminary design approaches. The TIR experiment is a ground-based sensor which will facilitate the SATKA function by producing data as the RVs reenter the atmosphere. Concept definitions for space-based radar are nearly complete. These concepts will focus technology on critical areas in the near term for boost and PBV surveillance and discrimination.

IR sensor performance improvements and radiation hardening are required by the space-based surveillance and tracking system. A critical supporting technology is the cryogenic cooling needed for sensitive IR sensors. A dramatic milestone occurred when the primary cryocooler design successfully demonstrated a 5-year lifetime. This proved the feasibility of an active cooler for the LWIR surveillance mission. Moreover, the integrated performance demonstration of the backup cryocooler design was also successful.

The technology considered most promising for the radiation hardened detectors has advanced significantly. Furthermore, operating temperatures for these devices have increased, thus reducing their cooling requirements. Superior radiation hard-

ness was demonstrated and detector noise has been dramatically reduced.

Reproducibility of high-performance LWIR detectors improved dramatically during 1986, due to success both in growing large single semiconductor crystals and the ability of multiple contractors to meet specified technical goals. The LWIR detectors will be used in a wide variety of SDI spaceborne and airborne sensors which are currently being developed.

Designs for wide field-of-view interceptor IR sensor systems were begun, and preliminary design review was held for a large test chamber for such systems.

Laser radars are needed both for precise target position determination and to support certain discrimination techniques. In the past year, new laser radar transmitters were designed and, in some cases, fabrication began. These include high-resolution IR lasers and UV lasers for additional discrimination techniques. Laser beam agility techniques were also defined, and some have been tested at low power levels.

Interactive discrimination technology must be developed to support a robust discrimination capability against a responsive threat and to ensure against potential countermeasures. This year a major study assessed more than 40 different interactive discrimination concepts and developed a technology program plan.

Signal processing technology is vital to all sensor developments. Furthermore, processors must be able to operate in radiation environments to ensure an effective strategic defense. Radiation-hardened chip technology continued to develop and included demonstrations of several different types of hardened chips. Over 5000 radiation-hardened chips implementing a

standard logical design were fabricated at five different VHSIC contractors, demonstrating a new standard for mass production of chip manufacturing. In support of the space-based real-time signal processing program, versions of the Advanced On-board Signal Processor (AOSP) nodal control unit and macro-functional signal processors were constructed. Work was initiated for VHSIC implementation.

To support both technology development and validation experiment planning, two general classes of measurements and data collection are essential: collection of data on Soviet ICBMs and their components (or surrogate/simulated targets) and measurements of the backgrounds against which these systems must be viewed. In the past year, SATKA sensors viewed targets against a variety of backgrounds, including the earth's lower atmosphere (earth-limb) and the various natural events that occur in this regime, e.g., the visibly intense aurora in the northern latitudes. SPIRIT I, a rocketborne earth-limb experiment, flew successfully during an extremely strong aurora and identified previously unseen phenomena. The instrumentation was recovered and can be flown again with improvements based upon the results of the first mission. This experiment was important because it demonstrated the ability to characterize an aurora against the earth-limb, thereby gathering critical data needed to evaluate the performance of an IR system during redout produced by a nuclear detonation.

In areas where the technology is sufficiently mature, technology validation field experiments are essential precursors to operational systems. It is essential to design experiments which test out both individual system components and the interaction and interrelationships among those system components.

Technology validation experiments are being pursued as follows:

- Initial planning for the SATKA Integrated Experiments (SIEs) required to examine the interactions among different sensors was completed and design was initiated. Planning was accomplished for later flights using test targets.
- Three contractors completed concept development efforts for demonstration/validation of the Boost Surveillance and Tracking System. The boost surveillance sensors are needed to detect ballistic missiles in the early phases before RVs and decoys are released to compound the problem.
- A concept was defined and source selection conducted for a space-based midcourse Surveillance and Tracking Experiment (STEP) to investigate critical surveillance functions for the Space Surveillance and Tracking System (SSTS) Experiment. However, STEP was canceled due to Congressional budget reductions. The mid-course system is needed to discriminate the warheads before entering the earth's atmosphere. The SSTS experiment has been delayed due to funding constraints.
- Two independent contracts were awarded to plan technology validation experiments and define preferred concepts for the LWIR Probe. Missions and payoffs of the probe in both the SDI ground- and space-based architectures were defined.
- The Airborne Optical Adjunct (AOA) program provides for the design and development of an IR sensor which, together with the appropriate data processing, display, control, communications, and ancillary equipment

will be installed on a modified commercial aircraft. The AOA capability will be to bulk filter, acquire, track, predict impact points, discriminate, and hand over data in real time to a ground-based radar. In 1986 the aircraft cupola panels, sensor optical bench, and the first flight node data processor were fabricated. The real-time operating software (for tracking, discrimination, and handover) was completed. The AOA experimental system CDR approved design plans and continuation of the experiment. Progress continued on experiment fabrication and modification of the 767 aircraft.

#### SATKA Program Overview

To accomplish the stated technical objectives and provide the confidence necessary, the SATKA Program has been structured with three basic thrusts:

- Technology Development. The SATKA Program is performing research in those areas of the technology base which support the highly responsive, survivable, and reliable sensors required by the SDI to operate in adverse environments. These efforts are concentrated in seven technology areas: radar discrimination, optical discrimination, imaging radar, laser radar, IR sensor, interactive discrimination, and signal processing.
- Technology Validation Experiments. The SATKA Program contains a number of experiments designed to validate the various concepts which have been proposed. These concepts range from relatively mature technologies like those employed in boost-phase surveillance and tracking and the terminal-phase imaging radar to relatively new, undemonstrated, concepts such as the long-wavelength infrared midcourse surveillance and

tracking and airborne LWIR terminal surveillance and tracking. The program includes the BSTS experiment, SSTS experiment (currently on hold status), AOS experiment, TIR experiment, and the SATKA Integrated Experiments (SIE).

### C. DIRECTED ENERGY WEAPONS (DEW) TECHNOLOGY PROGRAM

#### Technical Objectives

The Directed Energy Weapons Technology Program identifies and validates the technologies for directed energy systems that can:

- Destroy large numbers of enemy boosters and post-boost vehicles in the tens to a few hundreds of seconds that the missiles are in their boost phase, and
- Discriminate decoys from warheads by probing with an energy beam that interacts with the target in one of several fundamental ways to produce a distinctive signature that is difficult to disguise.

Those two missions--boost and post-boost phase intercept and midcourse interactive discrimination--are key to achieving a highly effective ballistic missile defense. Thus, the technologies advanced by the DEW Program are critical to providing a wide selection of defense options for the President's Strategic Defense Initiative.

In defense architectures, directed energy concepts could provide interactive discrimination in the midcourse phase. In addition, they could defeat tactics designed to avoid kinetic energy weapons deployed for boost-phase intercept. Over the long term, directed energy weapons appear to be the key to defeating the more serious threats that might be deployed in response to first-generation U.S. defenses, such as fast-burn boosters which severely shorten the exposure time of enemy missiles in their vulnerable boost phase.

This program pursues directed energy weapons concepts that include not only those that have emerged since the start of the SDI but also those that predate the SDI Program by several years and are more technically mature. The program also

emphasizes innovative technology. New forms of directed energy weapons concepts are continually emerging and creating options that may significantly improve system performance and/or reduce costs. The DEW Technology Program addresses four basic concepts, with several variations identified within each concept. These concepts are space-based lasers (SBLs), ground-based lasers (GBLs), space-based particle beams (SBPBs), and nuclear directed energy weapons (NDEWs).

The space-based laser concept (depicted in Figure VI.C.1) envisions self-contained laser battle stations. These battle stations are seen as modular assemblies of laser devices and optical phased arrays that can increase their performance by adding additional modules as the threat grows. The stations would be deployed in orbits to ensure the required number of weapons can be available to counter ballistic missile launches wherever they occur. Once deployed, such stations could engage ballistic missiles launched from anywhere on the earth, including sea-launched ballistic missiles and intermediate-range ballistic missiles. The SBL constellation could play other very significant roles. They could destroy post-boost vehicles before all reentry vehicles are deployed, destroy or identify decoys or penetration aids in the midcourse phase, and defend U.S. satellites. Furthermore, since the beam of some types of space-based lasers could penetrate the atmosphere down to the cloud tops, SBL weapons may be able to provide some capability against aircraft and cruise missiles, and tactical ballistic missiles.

The primary candidate for the space-based laser concept uses chemical lasers fueled with hydrogen-fluoride. Such lasers operate in the infrared at 2.7 micrometer wavelengths. This concept has been under development since the late 1970s. As the first DEW concept identified for ballistic missile defense, it is the most mature. The efforts are well into hardware

**HIGH BRIGHTNESS  
SINGLE APERTURE CONCEPT**

**VERY HIGH BRIGHTNESS  
PHASED ARRAY CONCEPT**

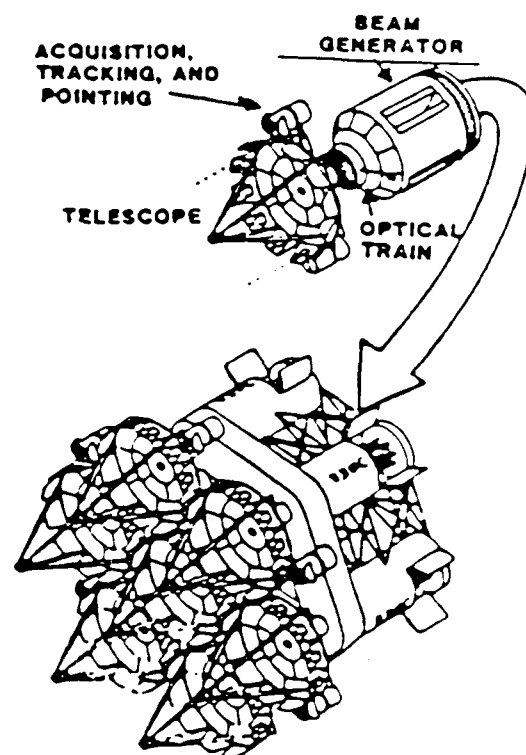


Figure VI.C.1 The Space-Based Laser Concept

fabrication for engineering proof-of-principle demonstrations in ground-based tests.

Other candidates for space-based lasers are devices that generate beams at short (about a micrometer or less) wavelengths. Since brightness--a primary measure of performance--scales as the inverse of the wavelength squared, the shorter wavelengths of those devices can provide substantial increases in brightness if the quality of the optics and accuracy in pointing is increased proportionately. The radio-frequency linac (RFL) free electron laser (FEL), for which high efficiencies are projected, is one of the most promising alternatives. Another candidate is the short-wavelength chemical laser. Yet another approach uses nuclear reactors to pump a short-wavelength laser.

The ground-based laser (GBL) concept is depicted in Figure VI.C.2. In this concept, several ground sites are equipped with laser-beam generators; target acquisition, tracking, and pointing; and advanced beam control subsystems. These stations generate a short-wavelength beam, condition the beam to compensate for atmospheric distortion, and project the beam onto space relay mirrors. These relays, perhaps at geostationary orbit (36,000 km), redirect the beams from the ground to mission mirrors at lower orbit. The mission mirrors acquire and track the target, point the beam, focus the beam, and hold it on the target until enough energy is deposited to kill the target. By this means, ground stations located in the United States can engage targets worldwide. As in the case of the SBL, such a weapon system has potential not only for defense against ballistic missiles but also for aircraft and satellite defense. Due to recent significant progress, the free electron laser appears to be the most promising approach for this concept. The GBL concepts have been under investigation since the early 1980s, and were accelerated as a result of the SDI. Budget restrictions have caused a significant slip in the schedule for excimer lasers, however.

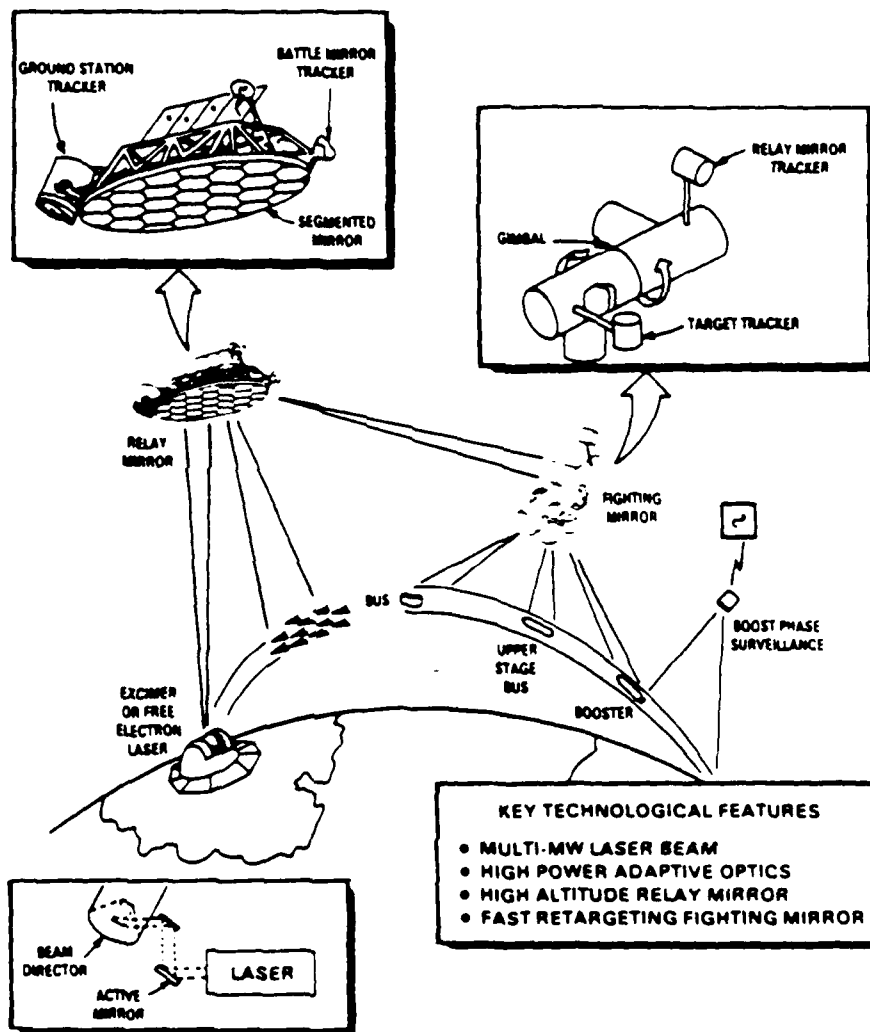


Figure VI.C.2. The Ground-Based Laser Concept

The space-based neutral particle beam (SBNPB) concept is depicted in Figure VI.C.3. In this concept, electromagnetic fields accelerate negative hydrogen ions. Conventional accelerators used by particle physicists use similar acceleration methods. Large numbers of these ions are accelerated to velocities near the speed of light, creating a high-energy beam which is steered toward the target by magnets at the front of the weapon. To create neutral particle beams, an electron is stripped off the negative ion as it leaves the weapon. A neutral particle beam does not diverge as it leaves the accelerator like a charged beam would. Charged particle beams may be useful against targets in the thin upper atmosphere. They could propagate in an ionized channel created by a laser beam, thereby forming a conducting path to the target.

The neutral particle beam weapon concept, as with space-based lasers, envisions a configuration of weapons platforms in space to provide worldwide coverage. These platforms could engage targets above the earth's atmosphere (i.e., late boost, post-boost, and midcourse phases). Unlike lasers, the energetic particles penetrate deeply into the target. Thus, a high-intensity particle beam can penetrate the thermal protection provided to survive reentry and destroy reentry vehicles in midcourse.

Neutral particle beam weapons have two potential kill mechanisms: electronics kill and hard kill. Electronics kill might be possible at relatively low beam fluence levels, but one might not be able to tell that the target has been killed. Hard or structural (readily observable) kill requires several orders-of-magnitude greater fluence than electronics kill. Prior to the SDI, hard-kill technology was proceeding at a fiscally limited pace; it has now been accelerated.

The newest, and potentially earliest, application of space-based particle beam battle stations could be used as

discriminators during the post-boost and midcourse phases. The primary targets would be decoys that are difficult to detect using passive means. The gamma rays and neutrons emitted by an object when irradiated by an energetic particle beam are proportional to the mass of the object. Thus, these emissions can discriminate the heavy reentry vehicles from the lighter decoys and penetration aids that may be encountered during an attack. Effective discrimination would decrease substantially the false targeting rate, thus conserving midcourse and terminal weapons resources for real targets.

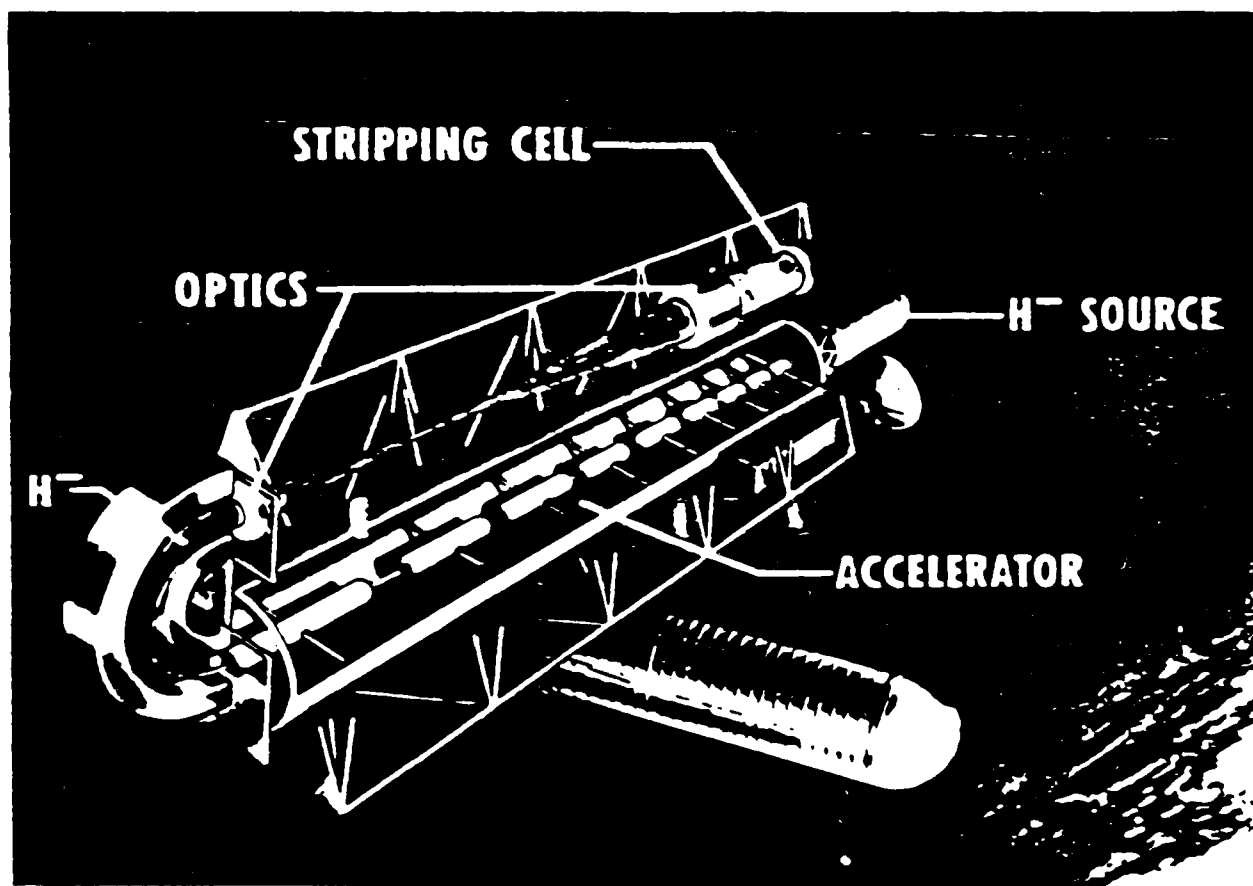


Figure VI.C.3. The Space-Based Neutral Particle Beam Concept

The fourth set of concepts--nuclear directed energy weapons--are being pursued by the Department of Energy. The DOE is conducting a broad-based research program investigating the feasibility and utility of using nuclear explosions to drive directed energy weapons technologies. These concepts seek to convert a portion of the energy released in a nuclear explosion into a form which can be concentrated and directed over long ranges onto ballistic missiles and their warheads. Such concepts may yield very high brightness over large lethal volumes. Some concepts, such as the X-ray laser, could be placed in ground-based interceptors that pop up to engage missiles early in their trajectory phases. While the Strategic Defense Initiative is emphasizing nonnuclear defensive weapons, this research is important to the overall understanding of the potential use of NDEW as an element of a U.S. defense, as well as the implications for its use in Soviet defensive and counterdefensive capabilities.

In applying the four directed energy concepts just described to potential missions and threats, a wide range of performance is required. Brightness (defined as the power per unit solid angle of the beam) and target hardness help determine how long the beam must dwell on the target to kill it. When combined with retarget time (how quickly one can switch between targets), the capability of the directed energy weapon is essentially defined. The basic technical objective is to provide a proven set of technologies which can produce a weapon with high brightness and short retarget times needed to meet specific ballistic missile defense requirements.

#### Significant Accomplishments

Building on efforts that predated the SDI and new efforts that have started since the Initiative, the DEW Program momentum and progress are increasing. Major achievements in chemical laser technology include experiments that have yielded the brightest laser outputs in the free world. Precision optics

fabrication for very large mirrors and complex shapes have been exhibited. These advances plus new experiments in combining chemical laser outputs in optical phased arrays have provided substantial new evidence of the feasibility of achieving high-brightness space-based lasers. Advances in free electron lasers have given impetus to a much more aggressive technical program for high-power ground-based lasers. FEL advances and successes in low-power atmospheric compensation have led to the formulation of a program to build a ground station for experiments in beam generation and atmospheric compensation. Dramatic advances in particle beam accelerators and the verification of a technique for determining the position of the particle beam relative to the target have encouraged new efforts for an early experiment to demonstrate interactive discrimination. Finally, new underground nuclear tests have added important evidence of the technical feasibility of several nuclear directed energy concepts.

Some specific examples of recent technical accomplishments in directed energy weapon technology are:

- Demonstration of high power and efficiency in converting electron beam energy into coherent microwave radiation in induction linac FEL experiments at the Electron Laser Facility. These experiments used the 3.5 MeV electron beam from the Experimental Test Accelerator (ETA) and also used a tapered wiggler as the microwave amplifier. A 10.6-m free electron laser experiment called PALADIN is being designed and built using the Advanced Test Accelerator. Component installation and preliminary experiments are now under way. Initial lasing from the PALADIN equipment occurred in November 1986 confirming theoretical predictions.

- High-power injectors have been designed and tested for next-generation electron accelerators that will drive future free electron lasers. Injectors with high-pulse repetition rates and accelerating modules using magnetic pulse modulators have also been demonstrated. A new design will soon be tested with higher electron currents, beam energies, and pulse repetition rates.
- Experiments on energy recovery have been completed and resonators for high-power FELs were tested. In addition, high-burst-power experiments at short wavelengths have been initiated in the pursuit of high-brightness radio-frequency-driven FELs for space- and ground-based applications.
- A definitive series of tests at the Advanced Test Accelerator is continuing to expand the understanding of laser-created channel-guided electron beams. The focus has been on understanding the dynamic interaction of the accelerating electron beam with the channel ions and secondary electrons. Of particular interest are:
  - Matching the electron beam between magnetic transport and laser-guided sections of the accelerator,
  - The effect of the laser channel on beam emittance growth, and
  - The impact of possible channel dynamics on the electron beam.
- Scalability of the ALPHA hydrogen fluoride chemical laser to brightness necessary for ballistic missile defense is being demonstrated. Very high brightness can be realized by the mutual phasing of multiple lasers in a manner that enables several individual

lasers to act as one giant laser. Recent work has detailed the physics of phasing several independent laser resonators with the resultant mutually coherent output. This is a revolutionary advance in state-of-the-art beam combining. It demonstrates the feasibility of scalable, modular designs with essentially unlimited total laser power applicable to both ground- and space-based lasers.

- The switching technology needed for excimer lasers to operate continuously and reliably has been demonstrated. Recently, a special switch was operated 100 times a second for 5 seconds at a voltage of 1.5 million volts. The excimer laser program is also addressing the problems of combining high-energy laser beams and of performing atmospheric compensation. Raman conversion cells are promising candidates to perform both these functions. Rapid progress is being made in both the beam quality and beam power produced by these cells.
- Beam control and atmospheric compensation technology were demonstrated in a series of experiments in which laser beams from the RADC AMOS facility in Maui, HI, successfully tracked U.S. Navy sounding rockets fired from the nearby Barking Sands Missile Range. Especially significant was the success in keeping a high-quality beam on the rocket at 10 degrees elevation, considering the greater thickness of the turbulent atmosphere transited. These tests demonstrate the ability to point at cooperative targets with high accuracy and to use adaptive optics to compensate for atmospheric turbulence, producing a beam quality close to optical limits.

- Metallic heat exchangers for high-energy laser mirrors were fabricated. These exchangers are the largest and most sophisticated ever made for this application. The mirrors, which represent a major advance in state-of-the-art large metallic optics, are the primary components of the ALPHA optical resonator which will extract laser power from the ALPHA gain generator. Also in ALPHA optics, the Large Optics Diamond Turning Machine (LODTM) successfully machined a non-axisymmetric optic. This capability allows design and optical fabrication of very large optical systems at significantly reduced costs.
- The LAMP program began assembling a 4-meter segmented mirror. This will be the largest lightweight mirror ever produced in the U.S.
- Cooled optical components, required by high-power free electron lasers to control thermally induced optical surface deformation, were developed. Three configurations with the potential to provide such thermal control have been designed; subscale samples are being fabricated for verification testing. In another optics effort, improvements in the peak and average power of FELs have required commensurate improvements in optics and coatings to handle the high-power beams without damage. Grazing-incidence mirrors expand the beam size, thereby reducing the power density on other optical elements. Recent experiments have demonstrated the feasibility of using these optics in high-power free electron lasers. This is the first time a grazing-incidence optical element of this size has been used in a laser resonator and still maintained good beam quality.

- The Accelerator Test Stand (ATS) was used to show the feasibility of producing high-brightness negative-ion beams for NPB systems. Experiments over the past several years have demonstrated that such beams can be produced in an accelerator only 4 meters long. The final phase of this demonstration increased the energy of the particle beam by a factor of 2.5. Successful operation in this new configuration indicates the feasibility of producing high-brightness negative-ion beams for space applications.
- A scaled-down TALON GOLD program was completed. This experimental program of integrated pointing control technologies demonstrated accuracies approaching those required for operational systems and increased understanding of how to point directed energy weapons with the extreme precision required. Portions of TALON GOLD equipment will be included in tracking and pointing experiments on the space shuttle.
- The initial round of conceptual design studies of the four DEW concepts was completed. These studies will provide inputs to the architecture developers on roles DEW concepts can play. In addition, these designs provide to the technology project managers the functions and performance needed from their technology.

#### Directed Energy Office Program Overview

DEW research efforts are consolidated into four principal projects under the Directed Energy Office. These projects are Technology Base Development, Technology Integration Experiments, Concept Formulation and Technical Development Planning, and Support Programs.

The Technology Base Development project expands the technological basis for directed energy weapons. Equally important, the project pursues alternate paths for achieving the critical functions of boost-phase intercept and midcourse interactive discrimination. Technologies being developed address the functions of (1) generating the beam; (2) conditioning the beam and delivering it to be propagated toward the target; (3) focusing and pointing the beam with high accuracy; and (4) acquiring the target, establishing the line-of-sight to the target, holding the beam on the target, assessing the damage, and reinitiating the sequence to rapidly engage new targets. Thus, this project includes work on various laser devices at various wavelengths; laser-beam control and associated optics; particle beam technology; acquisition, tracking, pointing, and fire control (ATP/FC); and NDEW phenomenology.

Technology Integration Experiments integrate and validate technology for selected concepts. These projects include (1) the Ground-Based Free Electron Laser (GBFEL), (2) the Neutral Particle Beam Integrated Space Experiment (NPB-ISE), and (3) Space Pointing, Acquisition, and Tracking Experiments (SPATE). These major experiments leverage opportunities for realizing significant technical achievements in specific promising concepts for boost-phase intercept and midcourse discrimination. Their selection to receive emphasis as a major project with major resources places them on the leading edge of the SDI Directed Energy Weapons Technology Program. In the case of space experiments in acquisition, tracking, and pointing, the technologies are designed to have a broad applicability across a range of SDI concepts--non-DEW as well as DEW. Both shuttle-launched (STARLAB) and expendable-vehicle-launched (PATHFINDER) experiments are under way.

The third project is Concept Formulation and Technical Development Planning (CF/TDP). CF/TDP analyses review and

evaluate technical requirements and provide conceptual designs of operational systems that relate to SDI system architectures. These analyses also identify the technology gaps and research needed to realize the conceptual designs. Thus, CF/TDP activities help identify and resolve critical DEW issues on a scale that establishes the technical feasibility of achieving system-level performance.

The last project, Support Programs, partially funds activities at the DoD High Energy Laser Systems Test Facility at White Sands Missile Range. This facility provides equipment and facilities for high-energy laser experiments and lethality and vulnerability testing of potential targets using a deuterium fluoride (DF) chemical laser. In addition, certain program management functions associated with execution of the SDI Program by the Services are funded by DEW. DEW also funds a portion of the Innovative Science and Technology Program, described in Section VI.F.

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kill vehicles for ballistic missile intercept and satellite defense; (2) ground-launched exoatmospheric interceptor development; (3) ground-launched endoatmospheric interceptor development; (4) miniature-projectile development for ground- or space-based modes; (5) test and evaluation of initial concepts, using hardware for functional technology validations; and (6) technology development related to allied defense and the antitactical ballistic missile. These projects include technology being developed all over the country, including numerous laboratories and universities.

Space-based kinetic-kill vehicles (SBKKVs) are most effective against the boost and post-boost phases of ballistic missile flight. The KEW Program is developing both an SBKKV flight experiment and the related technologies. These technologies include divert and axial propulsion, fire control and sensors, interceptor guidance, and SBKKV seekers. In 1986, the studies and lab experiments were completed to determine which system architecture would provide the highest performance at the lowest cost. A great deal of attention was also given to system survivability and countermeasures. In addition, considerable progress was made in the technology needed to produce lighter missile components, advanced propellants and motors, and high-performance missile seekers.

In FY 1987, a major SBKKV space experiment will be defined after end-to-end system simulations and ground testing of components. Technology development efforts will continue in propulsion, motors, guidance and control, and seekers to further reduce weight and refine technical goals.

For FY 1988 and FY 1989, the SBKKV project will continue to develop hardware, prepare for a space experiment, and expand on related technologies. A space flight will follow to validate the technology.

The ground-launched Exoatmospheric Reentry-Vehicle Interceptor System (ERIS) is a more mature technology that will provide intercept capability in the longest portion of an ICBM trajectory, the midcourse phase. Technology development supporting this system includes low-cost miniature kill-vehicle technology; advanced propellants and structures; and guidance, control, and missile electronics. For FY 1986, the SDIO's accomplishments include evaluation of electro-optic seeker designs, specifications for avionics and inertial measurement unit (IMU) components for guidance, preliminary tests of lethality enhancement devices, and determination of requirements for target handover from a surveillance sensor. Technology advancement for exoatmospheric systems also focused on miniaturizing kill vehicles, developing ultra-high burn-rate propellants, and demonstrating a two-order-of-magnitude improvement in inertial navigation.

In FY 1987, conceptual designs for both an ERIS operational missile and the test bed configuration will be completed. Appropriate signal processing will be developed to allow simulations of seeker performance against complex target suites. Lethality tests of enhancers to the kill vehicle will be completed. Exoatmospheric technology development, laser, passive infrared or ultraviolet, and millimeter-wave command links will be evaluated for midcourse guidance. Technologies for miniature kill-vehicle control will focus on advanced solid and liquid propulsion systems, explosive strips, and fluidics. Trade-offs in hit-to-kill designs, including point impactors and web-type warheads for expanding the area impact, will be investigated. Investigations will also begin in novel materials, design approaches, and improved manufacturing techniques to reduce projectile mass and cost and to ensure adequate ruggedness. Demonstrations of subsystems will continue.

In FY 1988 and FY 1989, preparations for the first flight experiment, including preliminary and critical design reviews,

will continue. The first launch is planned for second quarter, FY 1990.

The ground-launched High Endoatmospheric Defense Interceptor (HEDI) completes the KEW layered defense. HEDI will intercept reentry vehicles at the end of the midcourse phase and at the beginning of the final portion of ICBM flight, the terminal phase. Related technologies for this system include advanced seekers, windows, and avionics; warheads and fuzes; and advanced propulsion subsystems. In FY 1986, HEDI made significant progress, particularly in wind tunnel tests. Progress included successful tests of window cooling, boresight error, shroud removal, and preliminary verification of the interceptor aerodynamic characteristics. Initial results are very encouraging.

During FY 1987, the HEDI project will continue with wind tunnel tests and interceptor designs. Wind tunnel tests will include improved window cooling, jet interaction performance, and aero-optic testing. These tests will be at higher Mach levels and pressures than previously used data for selecting designs. Successful completion of these activities will significantly lower program risk. In FY 1988 and FY 1989 flight experiments will begin.

In the miniature-projectile area, the KEW Directorate is investigating several deployment options for these specialized warheads and launchers. Such projectiles might be used in both ground- and space-based modes, possibly with the interceptors described above. Though development is focused on meeting SDIO mission needs, small projectiles also have applications as ground-based tactical weapons for the U.S. Army and possibly as an antitactical ballistic missile defense system. Ongoing technology development efforts in this area include projectile miniaturization, rapid-fire capability, and specialized guidance and control.

A major task under the mini-projectile effort is Lightweight Exoatmospheric Advanced Projectiles (LEAP). In FY 1986, LEAP technology programs evaluated design concepts and conducted experiments for several projectile fire-control technologies. Advances in component technology (propulsion, structures, guidance and control electronics, IMUs) and supporting software strongly suggest a lightweight projectile is closer to development than originally thought. Accordingly, the Sagittar and Gremlin programs were redirected and combined to form a single miniature-projectile program, LEAP. The goal of this program is to test and build a lighter-weight projectile in 30 months.

In FY 1988 and FY 1989, the LEAP program will develop, fabricate, and test hardware (via hardware-in-the-loop simulations) for miniature projectiles and for fire-control subsystems. Emphasis will be on miniature IMUs, Very High-Speed Integrated Circuits (VHSIC) Phase I hybrid circuits, and miniature strapdown seekers. This hardware should be completed by the end of Calendar Year 1988. Assembly of the miniature projectiles should begin in CY 1989. Fully functional projectiles will be tested by the third quarter, FY 1989. In FY 1986, LEAP technology programs evaluated design concepts and conducted experiments for several projectile and fire-control technologies.

Another task in the mini-projectile area is Hypervelocity Launcher (HVL) technology. The FY 1986 HVL accomplishments include:

- Advances in the TIER I and TIER II Hypervelocity Gun (HVG) program. This program emphasizes increasing HVG projectile mass and velocity, improving launcher efficiencies, and the design and fabrication of the Mark IV gun by the Air Force Armament Laboratory (AFATL).

- A successful rapid-fire test of a switch with a capability to fire 40 times faster than any other switch previously tested.
- Successful test of an advanced compulsator design for a HVL, which could produce a less complicated and cheaper HVL alternative.
- Breakthroughs in understanding the physics of HVL bores.
- Successful launches by different companies of various masses up to 5 km/sec with little or no barrel erosion.
- 100,000g launches of focal plane arrays, batteries, amplifiers, propellants, and other electronic components.

These efforts will continue in FY 1987.

The Test and Evaluation efforts provide for functional technical validations (FTVs) of initial concepts through instrumented test flights both within and outside the atmosphere. These test flights collect data that are currently unavailable; they provide information for the eventual deployment decision and form the basis for other experiments that need to be conducted. Included in these efforts are two significant technical milestones (STMs), all range support targets and hardware-in-the-loop simulations.

In the STM arena, STM-I, also known as Delta 180, flew on September 5, 1986. This experiment was a success. The flight, which was conceived, designed, built, and executed over only a 14-month period accomplished all scientific objectives beyond expectations. Delta 180 accomplishments included plume

phenomenology measurements and a high-speed space intercept with both intercept vehicles under thrust. It was America's first successful space launch since the Challenger accident.

The primary purpose of the next STM flight, Delta 181, is to collect further phenomenology data for SDIO flight experiments and, in particular, the data required to support the SBKKV early flight experiment. The STM flight is scheduled for FY 1988, and it is the primary information source for the SBKKV flight experiment data. Range support targets and hardware-in-the-loop simulations have supported the programs listed above and will continue to do so.

The last KEW category, Allied/Theater Defense, includes as its main effort, the Theater Missile Defense/Foreign Technology Program. The objective of the Foreign Technology effort is to evaluate and develop allied technology based on uniqueness and applicability to SDIO's KEW regional (theater) defense architectures. The tasks selected will be short (3 years or less) and relatively inexpensive. As a technology matures under this program, it will be folded into work being performed by one of the SDIO Service agencies. Principal areas of endeavor under the program are:

- Electromagnetic Rail Gun Technology (United Kingdom): Perform subsystem research in switches, barrels, projectiles, instrumentation, and EMP effects in an enclosed, instrumented test facility using a 6.7 MJ rail gun. This research will include internal ballistics (brush and plasma armature), external ballistics (rectangle- and round-bore projectiles), and terminal ballistics (high-velocity projectiles). New materials, composites, and high-performance ceramics will be used in barrel development.

Feasibility demonstrations in linear motor design, including coupling the launcher to a high-speed injector for launcher concepts evaluation, will be conducted.

- Combined Chemical and Electrical Propulsion Scheme (Israel): This program will provide a new dimension in the rail gun technology program by adding the potential to increase the velocity of a rail gun's projectile by chemical means. This would reduce the weight of the gun barrel and the size of the power plant required for space and ground application.
- Exo Pop-up Antenna (Italy): This program will develop a millimeter-wave radar system to acquire and track reentry vehicles outside the atmosphere. The seeker will use an erectable antenna that will extend acquisition ranges and act as a lethality enhancer.

The SDI Antitactical Ballistic Missile (ATBM) Defense Program will perform research on simulation, component, subsystem, and interceptor technologies, and arrange for integrating and testing hardware for a theater defense architecture. These objectives will be accomplished under the following programs:

- Invite, Show, and Test (ISAT): Both U.S. and allied contractors will be invited to identify existing hardware or modifications to existing hardware for use in an interim theater missile defense system. Selected components, subsystems, or systems will be tested in test beds, ground test facilities, and/or by flight test.

- FLAGE Follow-on: FLAGE is a small, nonnuclear, hit-to-kill interceptor which uses an active radar and small, multiple divert thrusters. The program will develop the seeker and guidance and control technology for a short-range interceptor against complex radar-signature threats at low altitudes. The FY 1986 successes of this program are chronicled in the introduction of this section. FY 1987 will include two to three additional launches against targets with ever-increasing complexity.
- Combined Allied Defense Experiment (CADE): CADE provides system, test, and hardware support for all KEW regional (theater) defense programs.
- Extended Range Interceptor (ERINT): The ERINT will modify FLAGE technologies with increased radar seeker performance, a reduced-weight warhead with a fuzing function, larger attitude control motors, and a more powerful rocket motor. The engagement scenario and target vehicle will be configured to validate non-nuclear kill of a tactical missile at realistic velocities, altitudes, and crossing angles.

Thus, as stated previously, the KEW Program runs the full gamut of the SDIO mission, from boost phase to terminal/tactical defense. The SDIO is addressing each of these elements in detail and conducting live-fire tests while simultaneously developing the required parallel technologies, albeit at reduced funding levels. The KEW Program has already enjoyed several spectacular successes; other tests are planned from FY 1987 through FY 1990. These technology validation experiments, with the parallel technology development, represent a well-balanced, comprehensive approach.

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E. SURVIVABILITY, LETHALITY, AND KEY TECHNOLOGIES (SLKT)  
PROGRAM

Technical Objectives

The SLKT Program performs research in key technologies that are critical to the decision to develop and deploy a strategic missile defense system. Specifically, the SLKT Program supports research to:

- Develop the technology base that will allow the system architects and hardware designers to assure the functional survivability of potential strategic defense force elements in hostile environments;
- Reduce major uncertainties in predicting the Soviet's vulnerability to SDI weapons concepts;
- Coordinate and stimulate the development of power generation, conversion, and conditioning subsystems;
- Develop the space transportation architectures, vehicle concepts, supporting technologies, and vehicle systems which can meet deployment, maintenance, and cost requirements; and
- Identify, formulate, and manage focused, enabling materials and structures (M&S) research and development programs that leverage other ongoing DoD, NASA, and Department of Energy (DOE) M&S efforts to assure the availability of materials and structures needed for the engineering development of SDI systems.

The survivability project is tasked with generating the survivability technology base needed by the candidate strategic defenses. The project provides the SDI Programs and Systems Deputate and the hardware programs within the Technology Deputate with critical technical options and trade-off studies of

tactics and policy options needed for SDI functional survivability against defense suppression threats.

Using requirements generated from candidate architectures and approved threats, the survivability project has initiated Service/agency technology programs required to determine the potential of terminal and space system defenses. The passive hardening projects focus on nuclear, kinetic, laser, neutral particle beam, and RF/microwave threats to SDI systems. The survivability project also manages high-payoff technology projects for active survivability options such as decoys, warning sensors, and jamming devices.

SDI's proposed weapons concepts will generate and transmit unprecedented levels of energy to targets in unique space environments. Also, strategic targets are not well characterized by any previous work which could present large uncertainties in our knowledge of weapons effects. However, the Lethality and Target Hardening (LTH) project addresses important weapons effectiveness issues. The LTH project is a comprehensive research program that studies damage-effects created by SDI weapons concepts and predicts the corresponding vulnerability of Soviet targets. This damage-effects work is anchored in the scientific method (theory, modeling, testing). The current LTH effects work includes: thermal, impulse, and repetitively pulsed lasers, as well as particle beam, kinetic energy, and high-power microwave devices.

Besides the weapons effects (lethality) work, the LTH project also studies material hardening from the Soviet perspective (offensive hardening). LTH conducts materials research to ascertain achievable levels for Soviet offensive systems. Once determined, these new hardening limits are again tested against SDI weapons concepts. From such an interactive process a new set of performance requirements is

generated for these defenses. This innovative approach to lethality and target hardening is designed to reduce uncertainties in weapons effects and assure robust concepts are pursued against the responsive threat.

The Space Power and Power Conditioning project coordinates efforts to develop large quantities of specially conditioned electrical power for space-based weapons; ground-based weapons; and space-based surveillance, communication, and battle management systems. The project includes four major areas:

- Analysis and assessment of power requirements and candidate concepts;
- Development of the SP-100 nuclear power subsystem for continuous power generation serve SDIO, NASA, and other agency needs, and serve as a source of energy for storage systems that provide battle power;
- Evaluation of multimegawatt concepts for further development; and
- Development of power conditioning/pulse power technology to improve performance and reduce weight/volume.

The feasibility of a multitiered ballistic defense system is dependent on the ability to provide high capacity, low-cost space transportation. The Space Transportation and Support project is investigating the space transportation architectures, vehicle concepts, and the technologies required to meet the SDIO requirements. A wide variety of expendable, partially reusable, and fully reusable vehicle concepts are being evaluated. Vehicle and operational issues under investigation include unmanned cargo launch vehicles, orbit-to-orbit transfer systems, and launch and flight operations. Study results

indicate that a new-generation unmanned heavy-cargo launch vehicle is an essential key to meeting SDI launch requirements. Advanced technologies focus both on improved performance and on enhanced operations for this vehicle.

The Materials and Structures project is a new start in FY 1987 which addresses the need for a centralized SDIO focal point and clearing house for new M&S technology developments. The technological challenge and breadth of the enabling M&S advances and breakthroughs required for the total operational SDI system have dictated the formulation of an M&S project that builds on the M&S technology base of the entire nation. Six major technology areas are under investigation: lightweight structural materials, optical system materials, tribological systems materials, power system materials, thermal management system materials, and lightweight structures. They are focused on critical path technology development thrusts that are tied to major SDI experiments and system development milestones.

#### System Survivability

Description and Objectives. As candidate SDI architectures and hardware designs mature, the survivability project is generating the technology base required to assure survivability of the defense against robust suppression threats. The project is structured to identify promising active and passive approaches that include technologies, tactics, and evaluation of their effects on system survivability.

Both space-based and ground-based (terminal) systems must survive and remain effective after direct attack. The ability of an SDI system to intercept ballistic missiles will be determined by the survivability of candidate defenses. The U.S. can expect the Soviets to plan a sophisticated defense suppression attack on SDI systems. It is the responsibility of the

SDI to postulate defensive systems with sufficient survivability capabilities to make a Soviet attack relatively costly and unnecessarily complicated and make the outcome too uncertain to warrant initiating the attack.

Significant Accomplishments. The survivability project generated a technology roadmap in March 1986 to identify critical survivability technologies and guide the size and timing of the investments. From several hundred projects, the U.S. Army and Air Force survivability agents prioritized the top 70 critical activities requiring funding in FY 1987. The technology roadmap process is a rigorous, documented approach to allocation of limited funding. The process will be repeated annually, using the most mature candidate architectures and the latest threat projections.

The Defensive Shield Demonstration performed the first kinetic projectile tests on samples of baseline spacecraft armor. The baseline design performed better than expected against the hypervelocity projectiles. Weight of the baseline armor is much lighter than conventional approaches to pellet protection.

Independent survivability evaluations were performed by the five Phase II Architecture Studies contractor teams. Specific recommendations already have affected, for example, space-based kinetic-kill vehicle warhead designs. The findings from the evaluations will be used in tailoring survivability taskings from the contractors in FY 1987.

The first numerical justification for synergistically applying multiple survivability options to architecture designs were completed. Findings verified that first order simulations previously performed may have reached results far less favorable to the defense than now indicated. When trades are performed among multiple survivability options such as hardening, shoot-

back, electronic warfare, maneuvering, and decoys, the resulting probability of survival is much higher than previously expected. The effects on reducing the number and complexity of defensive assets now are beginning to emerge.

A star tracker design hardened to the near-term threat level nuclear environments was produced and tested (Figure VI.E.1). Star trackers will be an essential part of satellite attitude, navigation, and autonomy subsystems. Additional tests will be performed this year to determine ultimate hardness of the near-term star tracker design.

Extensive testing and design validation efforts were performed for laser-hardened satellite components. This will continue to be a major portion of the survivability project.

#### Lethality and Target Hardening

Description and Objectives. This project determines for each SDI weapons concept, the required lethal energy (kill criteria) to achieve a "sure kill" against the full spectrum of enemy targets. Both hardened and unhardened targets will be considered. The Lethality and Target Hardening (LTH) project results will reduce current weapons effectiveness uncertainties. This project stresses understanding the basic theory, developing predictive models, and validating by tests. Validation tests are conducted at both subscale and full-scale level. The predictive models developed will assist both weapons designers and system architects in making weapon effectiveness trade-offs.

The LTH project generates needed scientific data. For example, the High-Energy Laser System Test Facility (HELSFT) at White Sands Missile Range is used to assess booster vulnerability to high intensity continuous wave lasers. The particle beam test facility at Brookhaven National Laboratory, which

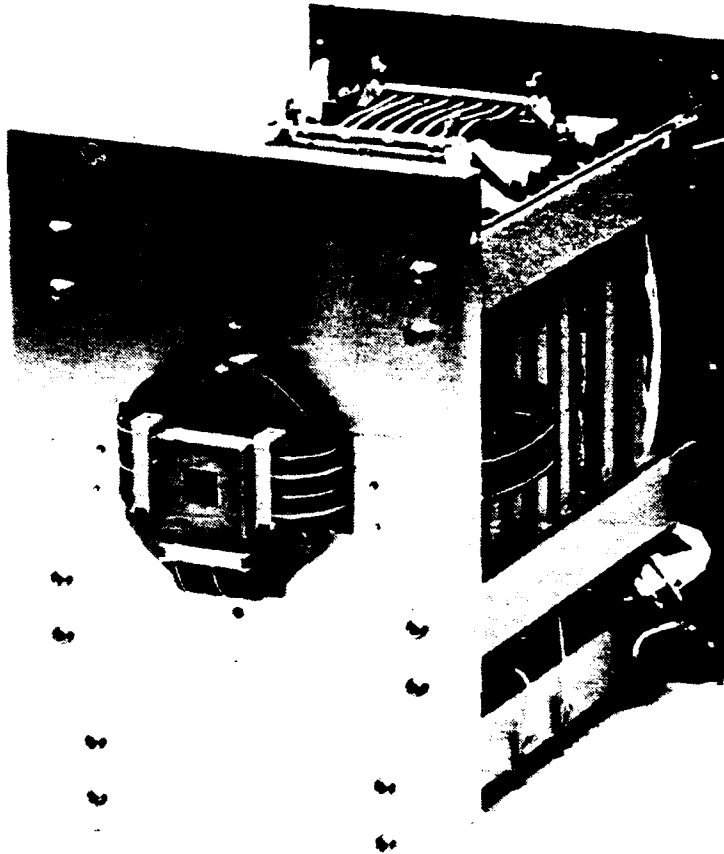


Figure VI.E.1 (U) Star Tracker Design

became operational in 1986, will be the site of future interactive discrimination experiments. In addition, the kinetic energy effects program will test the hypervelocity regime when the Los Alamos Test Facility becomes operational in 1987. Finally, effects work in high power microwaves will wind down in 1987 as the program completes a series of tests against a post-boost vehicle (PBV). The results of these tests and all the other tests mentioned feed into an annual lethality assessment document. This document is used by the weapons designers

as well as the system architects for concept design and trade-offs.

Significant Accomplishments. In years prior to SDI, various Service and agency programs examined vulnerability and target hardness issues for various weapons systems. Many of these programs were integrated into the SDI LTH project in the FY 1985-FY 1986 period. In addition to program integration, the following technical achievements were attained:

- Continuous wave laser tests were conducted at HELSTF in 1985 on full-scale solid and liquid boosters under simulated flight loads. The missiles were destroyed and failure models correctly predicted the failure temperature and time conditions.
- Impact tests with kinetic energy projectiles were performed in 1985 and 1986. In the quarter scale test an 18-gm fragment was fired at both a post-boost vehicle (with RVs) and a liquid-fueled target (Figure VI.E.2). The test validated a three-dimensional Eulerian code that uses the Lagrangian-follower technique to model damage. Development of an electromagnetic accelerator test bed was initiated at Los Alamos National Laboratory.
- A dedicated particle beam test facility at Brookhaven National Laboratory was completed in FY 1986. The first major test, completed in July 1986, was PLATO (Preliminary Lethality Assessment Test Object).
- Single-pulse-laser coupling experiments were performed using a variety of target materials fluence levels which verified the accuracy of existing computer simulation codes. These experiments were

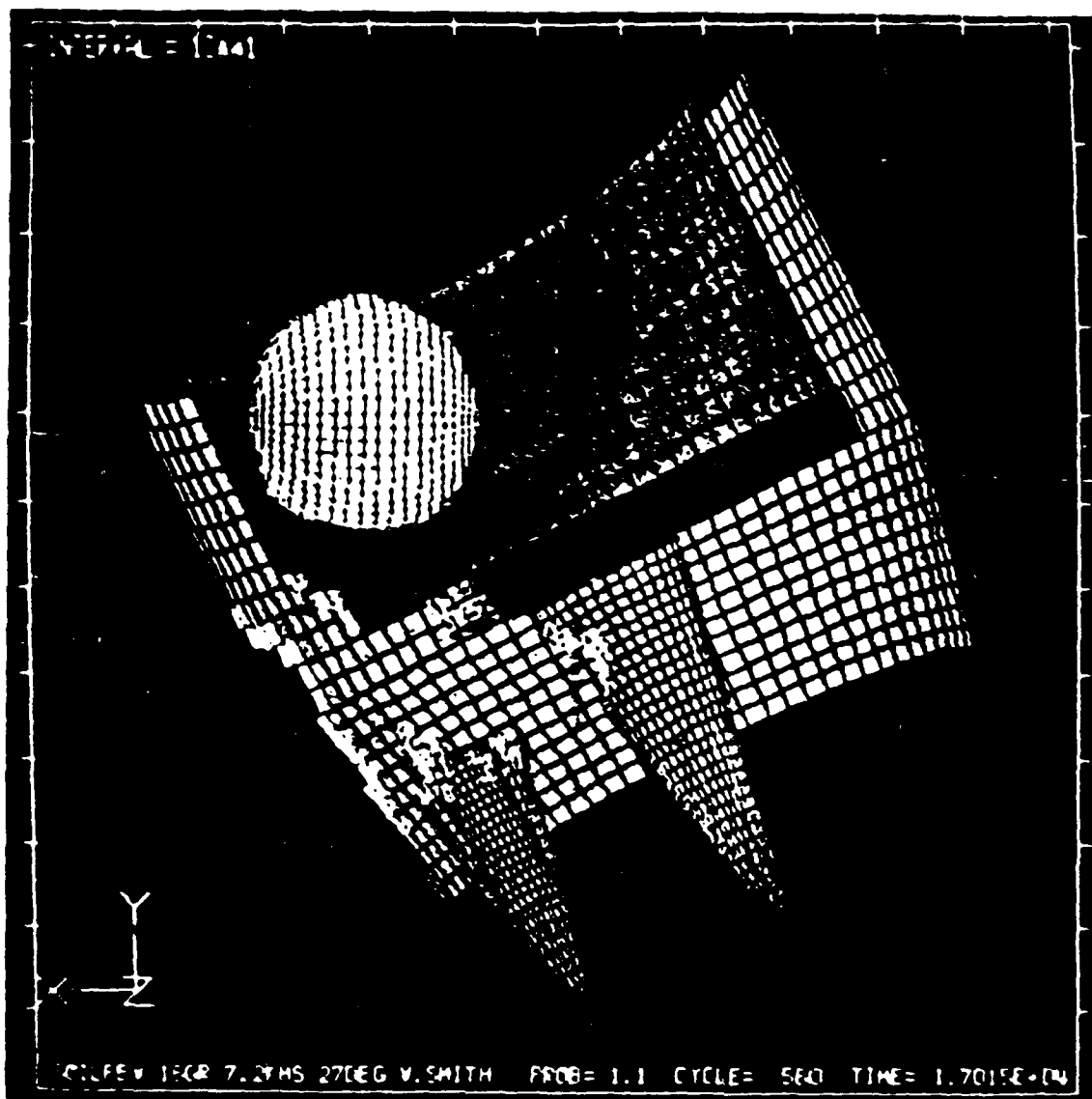


Figure VI.E.2. Computer Prediction of RV Damage  
(Excellent Match to Actual Damage)

conducted on the SPRITE laser in the United Kingdom, as well as an excimer laser at Los Alamos.

- In FY 1986, a series of tests was conducted to determine the lethality of high-power microwaves against hardened PBVs.

#### Power and Power Conditioning

Description and Objectives. Continued development of sensor and weapons systems concepts has reinforced the conclusion of the Fletcher Study that overall success of a layered strategic defense is highly dependent upon the ability to generate large amounts of electric power. The Power project has the responsibility to develop power generation and conditioning technologies capable of providing electrical power in the amount and form required by specific loads which will be a part of a defensive force. Megawatts for hundreds of seconds will be needed during the battle; baseload power of one hundred or more kilowatts will be required by weapon and sensor platforms over periods of years. Ground systems' power requirements are equally demanding in terms of total power required, although the weight and volume considerations associated with space development are not important. Four tasks are included in the Power project: (a) assessment and analysis of power subsystem concepts and requirements, (b) the joint SDIO-NASA-DOE development of a baseload power source (SP-100), (c) multi-megawatt (MMW) power research, and (d) power conditioning/pulsed power technology development.

The assessment and analysis task includes the power requirements definition and mission integration, space-power system architecture studies (SPAS), ground-power system architecture studies, and the assessment and evaluation of candidate concepts. A requirements document containing a comprehensive set of specific power requirements based upon the system architecture studies has been generated, and has been

reviewed by contractors conducting SPAS. The objectives of the power system architecture studies included investigating the effects of natural and system-generated environments on the power subsystem, the interactions between the power subsystem and other subsystems comprising the candidate space platforms, and development of multiple system architectures to be evaluated for total system effectiveness. To support Power and Power Conditioning project efforts, an Independent Evaluation Group made up of recognized government experts in the power field advises the SDIO on the technical merits, trade-offs, and technology needs of proposed concepts. The group identifies and tracks the evolving power subsystem requirements through coordination with other Program Elements under the SDIO, and provides power subsystems analysis and models to support SDI system architecture activities.

The SP-100 task represents an intermediate stage of development for high-power space-based systems. SP-100 is the cornerstone of the research and technology effort seeking long-term continuous power supplies. It is a 100 kilowatt-class nuclear-power generation subsystem that will have the potential for growth up to the 1 megawatt level. The SP-100 will furnish baseload power for space-based platforms in all the SDIO system architectures now contemplated and will form the main power generating capability (in conjunction with energy storage) for systems considered for near-term deployment. It will also act as an enabling technology for several NASA and non-SDIO military programs (e.g., space-based radar) planned for the 1990s. The major subsystems (reactor, power conversion, heat transport and radiator, and control) will be ground tested as of Phase II. A reference mission that combines the SP-100 with electric propulsion is targeted for a mid-1990s launch. The task is funded jointly by the SDIO, NASA, and DOE.

The multimegawatt research task was initiated in FY 1985 to address the projected SDIO requirements for both high level continuous power and burst mode power. The goal is to establish and advance the technology base to determine the feasibility of satisfying mission requirements within acceptable costs. Both nuclear and non-nuclear power sources are under consideration in open cycle and closed cycle configurations. The overall task strategy is to solicit and evaluate a broad spectrum of candidate concepts from industry and laboratories followed by a narrowing of the number of potential concepts. This is expected to occur in FY 1988, with focus placed on the primary technology efforts in support of the candidate concepts. Efforts would continue to develop the data base for these concepts in order to establish overall feasibility and enable design and development of a ground demonstration system starting in FY 1992.

Power conditioning/pulse power technology development addresses the special energy forms and delivery requirements for weapons and sensor systems. It is a broad-based effort that seeks to expand the existing technology base through fundamental research and development with emphasis on critical element development. Activities are guided via recommendations made by the ad hoc Pulse Power Technical Advisory Committee, a group of government, national laboratory, and university experts in the pulse power field. Work is presently concentrated on closing switch/environment interaction studies, inverter development, and other related technologies. Components which are more efficient, lighter in weight, and smaller in volume are being developed for space application. In many cases, much higher power throughputs will be required than available from existing state-of-the-art components, and major improvements in performance are required.

Significant Accomplishments. The Power and Power Conditioning project began in FY 1986. The SP-100 project completed

transition from Phase I, Technology and Assessment, to Phase II, Ground Engineering System (GES) testing. The current Phase (Phase II) involves developing and demonstrating the performance, safety, dependability, manufacturability, and technology readiness of the SP-100 power system concept, culminating in a 6 month full power ground demonstration of the reactor and comprehensive testing of the major subsystems at appropriate test facilities.

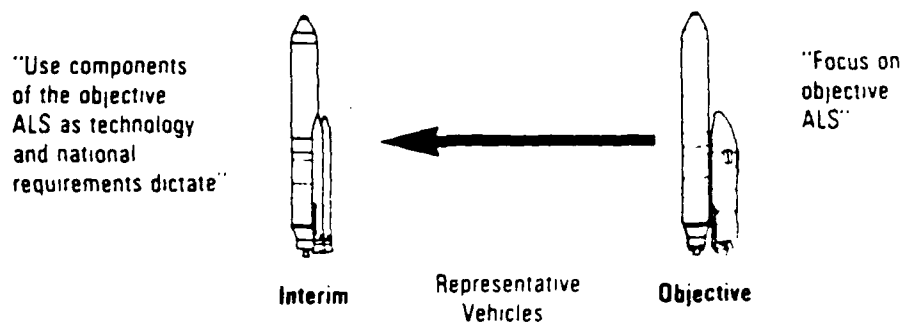
Fiscal Year 1986 was devoted to refining several concepts associated with technology needs for the MMW task. Additionally, the Nuclear MMW Project Office at the Idaho National Engineering Laboratory was established.

Significant accomplishments in the power conditioning/pulsed power effort included demonstration of 1 kJ/kG energy storage density in high voltage capacitors developed by the joint DARPA-DNA-SDIO capacitor development program; work continues to extend this value to 2 kJ/kG. In the closing switch program, a high-power thyatron operated for more than 30 minutes at an average current of 30 A, and anode voltage of 25 kV. The resulting average power switched of 750 kW is significantly greater than has ever been achieved in a switch of this type. Progress has also been made in understanding fundamental problems associated with operating spark gap switches in high voltage circuits.

#### Space Transportation and Support

Description and Objectives. The objectives of this project are to define optimal architectures and vehicle systems required to deploy and maintain strategic defense systems, programs to develop the technologies for a robust transportation system with significantly reduced costs, and development of new space transportation systems. It is clear that current space transportation systems lack adequate launch capacity and are prohibitively expensive to support the range of space-based missile defense systems envisioned for the SDI.

Space transportation systems must also support the broad range of national military and civilian needs in addition to the SDI support. Architecture studies favor a mixed fleet of manned and unmanned vehicles to satisfy national launch requirements, including the SDI. To meet the SDI requirements for reduced costs, this must be a new-generation vehicle incorporating high performance, an operational design, and advanced technologies. Design requirements include partial reusability, all liquid systems with high density, LOX/hydrocarbon propellants, and features which greatly reduce the support manpower in both launch and flight operations. Figure VI.E.3 illustrates how cargo vehicle components which meet near-term requirements might be designed using key technologies being developed for a far-term vehicle.



#### Design Philosophy

- Emphasis on operational flexibility not performance
- Reliable with goal of tenfold reduction in operations cost
- High capacity, robust
- Allows for contingencies and assured access to space
- Competitive design and development
- Optimum combination of advanced technology, manufacturing techniques, quality assurance practices and ground/on-orbit operations concepts
- Revitalize national space transportation technology base
- Proven, well-understood components

Figure VI.E.3 Advanced Launch System (ALS) Concept

Key technologies emphasize LOX/hydrocarbon liquid rocket propulsion; enhanced vehicle performance with lightweight structure, reusable propellant tankage, and lightweight electrical power; enhanced operations in adaptive, fault tolerant avionics, condition monitoring, and expert systems, and techniques for recovery and reuse of expensive launch vehicle elements.

Space Transportation. To preserve options for the deployment of a space-based missile defense system, in the early to mid-1990s, the SDIO is initiating technology development for an Advanced Launch System (ALS) in FY 1987. Concept definition studies in FY 1987 will lead to validation contracts beginning in FY 1988. The ALS will be designed to meet national launch needs and will utilize a design which can evolve to enhanced capabilities and reduced operations costs in the late 1990s.

Significant Accomplishments. The joint DoD-NASA Space Transportation Architecture Studies (STAS) have produced preliminary architecture and technology requirements results which have been transmitted to the NSC.

Multi-agency coordination has been initiated toward developing an integrated technology plan to support national space transportation needs.

Technology programs have been initiated in key areas which include LOX/hydrocarbon liquid rocket propulsion; clean, low-cost solid propellants; and the study of Space Shuttle launch operations.

#### Materials and Structures

Description and Objectives. Early in the SDIO research program, there was an implicit need for the research and development of materials and lightweight space and ground

structures. Several systems and critical technologies could not succeed if there were not parallel research and development efforts in this area. While there are fundamental, critical requirements toward which the SDIO must work, the area of materials and lightweight structures is one where the end users would especially benefit by improvement over and above the baseline system capabilities.

At the onset, it was believed that such technology could be brought along in association with existing projects. However, it became increasingly clear that individual activities could be more productive by combining common technology needs and coordinating and managing those materials and structures development activities by a central management approach. Additionally, this centralized approach would provide focusing and leveraging into the immense national M&S technology base.

This project will be responsible for developing those advanced materials that offer multifold performance and durability enhancements for a broad spectrum of critical SDI applications. For many of the SDI systems concepts to be successful, ten-fold improvements or greater in materials and structures properties and technologies will be required. For example, active cryocoolers, pointing and control mechanisms, and transportation system engine turbopumps could realize needed performance, life and weight improvements of this magnitude if the development and implementation of advanced ceramic structural components, and associated lubricants were realized. The development and maturation of lighter-weight, more durable structural composites will also provide sizeable system performance and cost pay-offs for ground-based interceptors, STS, and space-based platforms.

To assure that these mission-enabling technologies are available for FSED milestones, the SDIO M&S program is completing and refining the following crucial tasks:

- The identification of mission-enabling M&S requirements for systems development programs;
- The formulation of new M&S thrusts that address serious gaps or deficiencies in current and planned technology base programs for ground and space systems; and
- The leveraging of other ongoing Service, DNA, DARPA, NASA, and DOE M&S technology base programs that result in focused critical path M&S thrusts.

Significant Accomplishments. The identification and transition of relevant materials and lightweight space structures technology to the SDIO is continuing. When the SDIO Materials and Structures Office was initiated, there were a number of existing M&S programs within the Services, DOE, DARPA, and NASA that were beneficial to the SDIO. During FY 1986 these programs were identified and some of the ongoing efforts have been leveraged to provide acceleration and reorientation for high payoffs in the SDI Program with a minimal investment.

During FY 1986, to address the formidable coordinating and leveraging task, the SDIO M&S office formed six inter-agency technical planning panels to assess the critical/enabling SDI materials technologies, to include lightweight structural materials, thermal management materials, tribological system materials (bearings and lubricants), power system materials, and lightweight space structures. The panels were composed of experts nominated and selected from the Services, NASA, DOE, DNA, and DARPA. These panels will play a crucial role in developing and refining future M&S plans and their execution.

In late FY 1986, the six technology planning panels completed the review of SDI architectures, systems, and subsystems designs and identified critical M&S technology shortfalls and gaps. Five-year program plans were developed to achieve focusing, consolidation, and leveraging.

The U.S. Army and Air Force M&S Technical Requirements Documents (TRDs) were completed in FY 1986 for near-, mid-, and far-term SDI systems. A refinement to these TRDs will occur through FY 1987 as the system designs and architectures are further refined. An integrated (Army and Air Force) TRD to identify multifunctional applications will be completed in FY 1987.

Major accomplishments in FY 1986 were gained with the completion of the ring truss, tripod, and box truss structure of the dynamic test article (DTA), which has achieved 16% passive structural damping. Testing has verified that damping levels designed into this typical space structure have been met for all components. The ability to "design in" damping is essential for SDI spacecraft stability and control. Passive and active control of these lightweight space structures is critical for both kinetic and directed energy system platforms. A schematic of a scaled-down replica of the dynamic test article which illustrates the dynamic characteristics of a generic large-scale space structure is shown in Figure VI.E.4. Figure VI.E.5 depicts the actual experimental configuration of the DTA to test damping in large space structures.

#### Major Thrusts

The Defense Suppression Threat project was recently consolidated with the Offensive Threat task in the Strategic Information and Concepts Directorate. This change was made to expedite the review and dissemination of standardized threat data to the SDI architecture and hardware design offices.

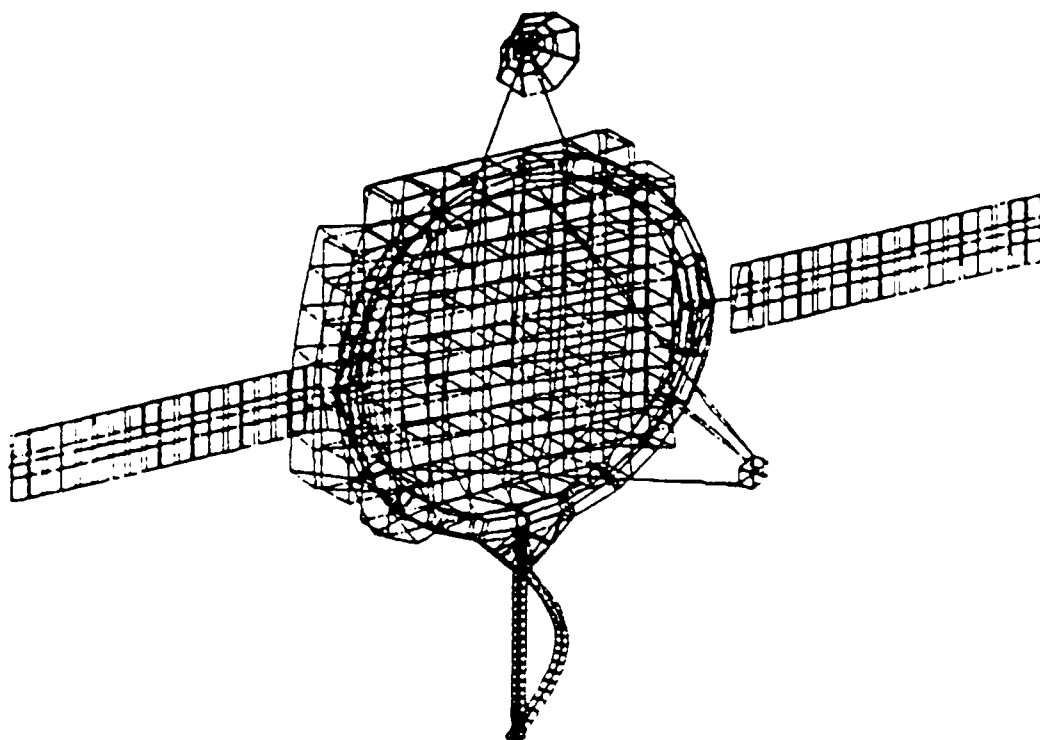


Figure VI.E.4    Artist's Concept of Dynamic Test Article  
                    Illustrative of Dynamic Characteristics  
                    of a Generic, Large Space Structure

The survivability project has been designated as the independent evaluator of the survivability of candidate hardware designs. The project is establishing the baseline environment levels in which systems designs must operate. The survivability project will evaluate the ability of the Technology Directorate designs to operate in the environment projected by the approved defense suppression threats. The survivability project will work in conjunction with the Strategic Architecture Directorate to establish these environment levels as baseline for the entire SDIO and to periodically update the levels to reflect changing architectures and threats.

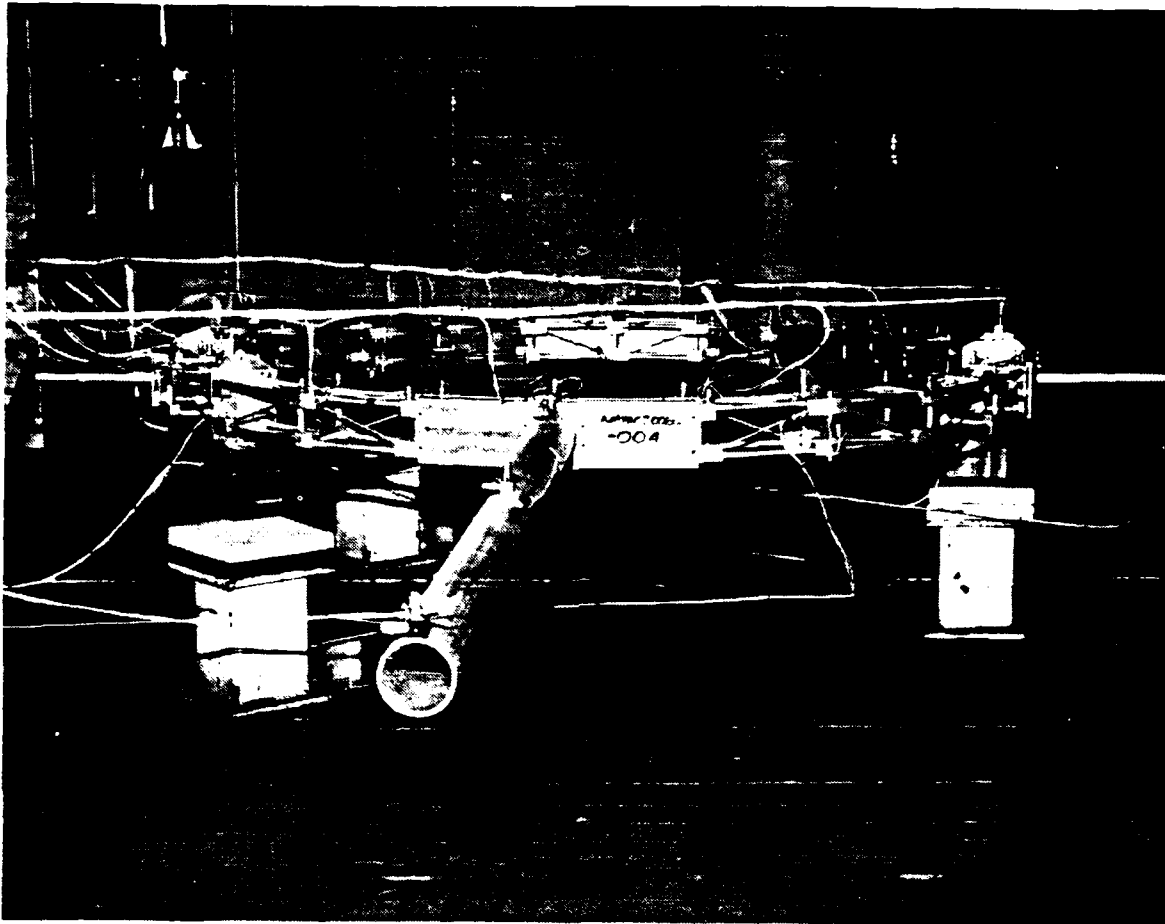


Figure VI.E.5 The Dynamic Test Article Experiment Configuration

A major study is being initiated to determine ways to achieve significant nuclear hardening of spacecraft by integrating different techniques at the beginning of satellite design rather than retrofit hardening. The study will initially look at the breakpoints where differing hardening approaches can be used. Subsequent studies will determine the specific technologies which must be employed to achieve requisite levels of hardening.

The Spacecraft Armor project will optimize the pellet shield designs generated in the first phase of the effort. The goal is significant reduction in the weight of the satellite armor when compared to conventional approaches. The shielding material will be tested for its effectiveness against other satellite threats.

Specific red/blue analysis of emerging architecture concepts will be conducted. The survivability project personnel will form a significant portion of the blue team for these analyses.

Reduced funding over the last two years has caused the Lethality and Target Hardening project to focus more on the near-term options.

Based on the availability of funds, the LTH project will become a participant in the SDIO's integrated experiments. The predictive models developed in the LTH project will assist the integrated experiments in pretest predictions. In addition, the LTH project will assist the integrated experiments in post-test analysis.

The SP-100 space nuclear-reactor power-source program will start construction at the Hanford test site in preparation for the full-power ground demonstration run. Fabrication of the reactor engineering model and all nonnuclear subsystems will continue, as will fuel pin manufacturing. A determination of the first flight mission will be made and design of the flight nuclear power system instituted.

The multimegawatt power source program will continue concept study and technology development of several nuclear, nonnuclear and hybrid space power sources. These systems, with power levels in the hundreds of megawatts class, will employ diverse industry engineering teams with technological

support from the national laboratories. Results of these studies will form the basis for plant design programs to start before FY 1989.

In the area of power conditioning/pulse power, a number of technical approaches will be down selected in FY 1988; the focus will be on technologies that address specific platform requirements and near- and mid-term launches.

Major FY 1988 thrusts in the Space Transportation and Support project will refine the definition of the space logistics architecture and vehicle concepts by developing preliminary designs for a new unmanned cargo vehicle options and examining on-orbit support and logistics systems. Further efforts will be directed toward development of technologies in high-payoff areas such as testing of LOX/hydrocarbon booster engine components, propulsion test facilities, structural component demonstrations (propellant tankage), subsystem hardware demonstrations (fuel cell power), recovery system demonstrations for propulsion avionics module application, and operations demonstrations (launch operations automation).

The Materials and Structures project areas of principle emphasis include the following:

- Power storage and heat rejection materials which are critical for a near-term SSTS capability option as well as the later Epoch systems.
- Advanced composites and manufacturing processes for substructures, rocket cases, and shielding. Thermostructural materials for kill vehicles are also near-term requirements for Army integration FSED milestones.

- New bearing, seal and lubricant materials to extend the life of space transportation system and orbital transfer vehicle engine turbopumps by an order of magnitude or greater.
- Ceramic structural elements, bearings and seals for active cryocoolers. These technologies, when mature, will permit the construction of coolers with improved performance and enhanced durability, and substantial reduction in power and the associated heat rejection and weight requirements.

Finally, it is noted that space-based surveillance and defensive systems platforms and subsystems are critically dependent on integrated active and passive control of large space structures. The FY 1988 M&S thrust is aggressively pursuing these technologies to include integrated structural dynamic modeling and validation, sensors and actuators for rapid slewing, and intrinsically damped materials.

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F. INNOVATIVE SCIENCE AND TECHNOLOGY (IST) OFFICE

Description and Objectives

The Innovative Science and Technology (IST) Office is the SDIO's technical division tasked with seeking out new approaches to ballistic missile defense. IST allocates funding to research new approaches and assures that the SDIO's other technical divisions are appraised of new results and breakthroughs emanating from IST programs. FY 1986 funding for the SDIO/IST effort was \$91 million (3.3% of the total SDIO appropriation). Of this amount, about \$12 million was used to fund research under the Small Business Innovation Research (SBIR) Program. The projected funding level for FY 1987 is \$126 million (4.0% of the total SDIO authorization) with approximately \$25 million being allocated to the SBIR Program.

The IST Office is responsible for:

- Establishing a technology base for strategic defense via fundamental research. This research is conducted by the scientific community in universities, government and national laboratories, small businesses, and large industries.
- Providing a window into SDIO programs for academia. Many of the new ideas and breakthroughs in basic science and engineering on which the success of the SDI effort may depend will be spawned, as they traditionally have, from university programs. In FY 1986, the IST Office funded over 90 university research groups from more than 60 different American universities.
- Administering the SDIO SBIR Program. This federally mandated program required that 1.0% of the total SDIO extramural R&D funding be allocated in FY 1986 to small businesses. This requirement increases to 1.25% in FY 1987.

The IST Office sponsors fundamental research programs in six major areas: (1) advanced high-speed computing, (2) materials and structures for space applications, (3) sensing and discrimination, (4) advanced space power, (5) advanced propellants and propulsion, and (6) directed/kinetic energy concepts. The research program is centrally managed by IST personnel and implemented through science and technology agents (STAs) located at other government agencies (such as the Office of Naval Research, Air Force Office of Scientific Research, Army Research Institute, Defense Nuclear Agency, NASA, DOE, and DoD laboratories). Proposal review, contracting, and day-to-day technical management of the IST research programs is the responsibility of the STAs.

#### Significant Accomplishments

The SDIO's IST research programs are less than two-years old. A number of significant accomplishments have been made on the many projects which have been accelerated by IST funding or from new projects initiated by IST. Some of the best examples of these are:

- The CHECKMATE (Compact High-Energy Capacitator Modular Advance Technology Experiment) electromagnetic launcher (EML) facility which was completed on time early in FY 1986 and within budget. This facility is capable of accelerating projectiles of 250 grams to velocities of 4-5 kilometers per second with a repetition rate of about two shots per day. This rate has been very important for expanding the EML data base which has heretofore been extremely limited.
- Researchers in the IST novel electronic materials program were able to fabricate monocrystalline films of gem-grade diamonds in the laboratory for the first time in this country. Diamond layers are extremely important for semiconductor electronics for several

reasons. They have: (1) five times better thermal conductivity than copper; (2) high breakdown strength at extreme electric fields; (3) inherently higher radiation tolerance than gallium arsenide; and (4) n-type carrier mobility higher than silicon. In addition they are chemically inert. Diamond films also have applications as coating layers on windows and optical devices because of their extreme hardness and transparency over a wide region of the spectrum.

- A new IST project in materials has resulted in substantial advances in producing optically clear, durable, large-diameter glass by using the low-temperature process known as Sol-Gel, Solution-Gelatin. The low-temperature Sol-Gel technology offers the potential for rapid, large-scale production of large, near-net-shape optical components with a wide range of optical and physical properties not possible with conventional glass melting methods requiring very high temperatures.
- Researchers in the IST space power program have a recently fabricated a prototype super-capacitor capable of storing 200 kJ of electrical energy in a can of less than 1 cu. ft. in size and 110 kg in weight. The enabling space power program technology was provided by the computer-aided molecular engineering of a dielectric of polyvinylidene fluoride and tetrafluorethylene with a dielectric constant around 14. This advance represents a factor of 4 increase in energy storage per unit weight over that which was attained by IST last year and reported in the FY 1986 Report to the Congress on the SDI and represents a significant advance in IST's thrust toward smaller, lightweight power sources for space applications.

- IST investigators have demonstrated super-current modulation in a Josephson Junction mounted on the back of a semiconductor substrate when the substrate was subjected to optical radiation. This provides the basis for a technique to fabricate extremely large, lightweight, infrared focal-plane detectors of an entirely new type to enhance SDI capabilities in sensing and tracking.
- IST university researchers working on ultra-short-wavelength lasers have successfully demonstrated lasing at about 1000 angstroms using a bench-top pumping laser with output energy of less than 1 joule. The significance of this breakthrough is in the area of electronic materials fabrication via laser lithography, where a compact, inexpensive source of coherent radiation below 1000 angstroms would be a powerful tool for the electronics industry.
- Chemical lasers offer the advantage of lower weight and less cost on orbit due to efficient, direct chemical conversion to beam energy. The major difficulty with existing chemical lasers is that they operate at long wavelengths and require large optical elements. IST researchers have recently produced and measured chemiluminescence reactions of the azide radical with carbon, oxygen, and phosphorus in a flow system. This is the first step in a source demonstration for a shorter-wavelength chemical laser which could be used with proportionately smaller optics.

#### Current Activities and Future Plans

In addition to the accomplishments in the previously described programs, the IST Office anticipates significant progress in many of the current IST-sponsored projects.

The Thunderbolt electromagnetic launcher program is scheduled to provide the first demonstration of acceleration of a projectile to hypervelocities (greater than 10 kilometers per second). The behavior of hypervelocity projectiles, power conditioning of EMLs, material erosion in the barrel, and effect on homing sensor electronics by the plasma generated in the gun are many of the issues to be investigated. The first hypervelocity demonstration is scheduled for the spring of CY 1987.

The requirement for compact accelerators for space applications, primarily in a discrimination role, is a very stressing one. The IST program in novel accelerator concepts has sponsored a research group to develop a spiral line recirculating induction accelerator which is lightweight, scalable, and has a high-gradient acceleration. The first milestone in this program is to demonstrate a 1 MeV beam with 1.5 kiloamps of current by the end of 1987, with the goal of increasing the beam energy [to 10 MeV] via recirculating the beam.

Present methods for detecting ballistic missiles in the boost phase rely on sensing infrared radiation from rocket exhaust. The IST Office sponsors a program to theoretically model (and eventually measure) the nonequilibrium ultraviolet (UV) radiation signature emanating from the continuous shock wave produced by the missile hard body. The problem is a difficult one, combining three-dimensional fluid dynamics with detailed nonequilibrium air chemistry, radiation transport, and UV spectroscopy. If successful, the program will define methods for detecting the missile body directly as opposed to the less accurate procedure of sensing radiation from the rocket's exhaust.

One of the most difficult problems for the SDI is software design. The high-level computer language requirements for battle management demand revolutionary techniques in software

development. A research group in an IST-funded program is working to develop a comprehensive, novel declarative computer language which could be used to design very efficient software for battle management. The demonstration of this language on a new fifth-generation computer is slated for demonstration in the near future.

To solve the batch processing problem of high-energy propellants which leads to many manufacturing difficulties (and also requires modular rocket engines such as those that powered the ill-fated NASA orbiter), the IST Office has groups conducting research to develop safe, automated, continuous processing techniques for high specific-impulse rocket fuels. The program is developing a twin-screw continuous mixer using Beryllium-based propellants which would contain about 500 times less material in the processor at one time. If successful, this process will vastly reduce the danger involved in the manufacturing process, allow for monolithic fabrication of rocket motors, and maintain the throughput of fuel rate presently attained by batch processing techniques.

To design novel composite materials for space structures, an entirely new class of materials is being researched by IST investigators. The research has focused on intermetallic-reinforced intermetallics which result in a particulate-reinforced composite material (formed as a result of an exothermic reaction). The product is expected to be a material that possesses high modulus, high-tensile strength, and an extremely high melting temperature. The goal is to produce a sample of this material in the coming months and characterize its properties.

Capacitors for space applications promise a high payoff in terms of energy storage and power conditioning for burst-mode weapon concepts. As a result of the diamond film research sponsored by IST and previously discussed, engineers are now

exploring the possibility of using diamond films as insulating layers in novel capacitors. Because of the high breakdown field strength, high thermal conductivity, and controlled layer growth of diamond, the application for capacitors is extremely promising for extending the energy storage now attainable with existing technology.

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## CHAPTER VII

### ORGANIZATION AND COMPTROLLERSHIP

#### A. ORGANIZATION DEVELOPMENT

The Strategic Defense Initiative Organization is an advanced technology program that was formed in 1984 from a collection of ongoing research and development projects identified by the Office of the Secretary of Defense to be SDI-related technologies. The SDIO Program Director was assigned in April 1984, and the Program was initiated with FY 1984 reprogramming appropriations. The SDIO is an independent defense agency whose Director reports directly to the Secretary of Defense.

The initial organization structure was established at 80 military and civilian personnel in late FY 1984. Since the SDI Program covers many technologies to be developed over a short period of time, the manpower requirements quickly increased to 125 positions in FY 1985 and 226 in FY 1986, corresponding to increased funding levels. This rapid growth in a 2-year period placed great demands on the organization structure to expand and accommodate Program requirements as they became more urgent.

The SDIO Director requested in 1985 that a study be conducted to streamline the organization and focus on centralized planning, direction, and control. This effort resulted in realigning the organizational structure to reflect current and future programs and personnel projections. The revised organizational structure was adopted in July 1986 and issued as shown in Figure VII.1.

The SDIO Charter was signed and issued by the Deputy Secretary of Defense in February 1986. It defines the responsibilities and operating relationships among the SDIO and other DoD organizations, the Services, defense agencies, other

government agencies, and private industry. The Charter also establishes the SDI Executive Committee (EXCOM) to provide DoD oversight for the management of the SDI Program. The EXCOM provides formal review of the program for the Secretary of Defense and is chaired by the Deputy Secretary of Defense. The SDIO Director serves as Executive Secretary of the EXCOM.

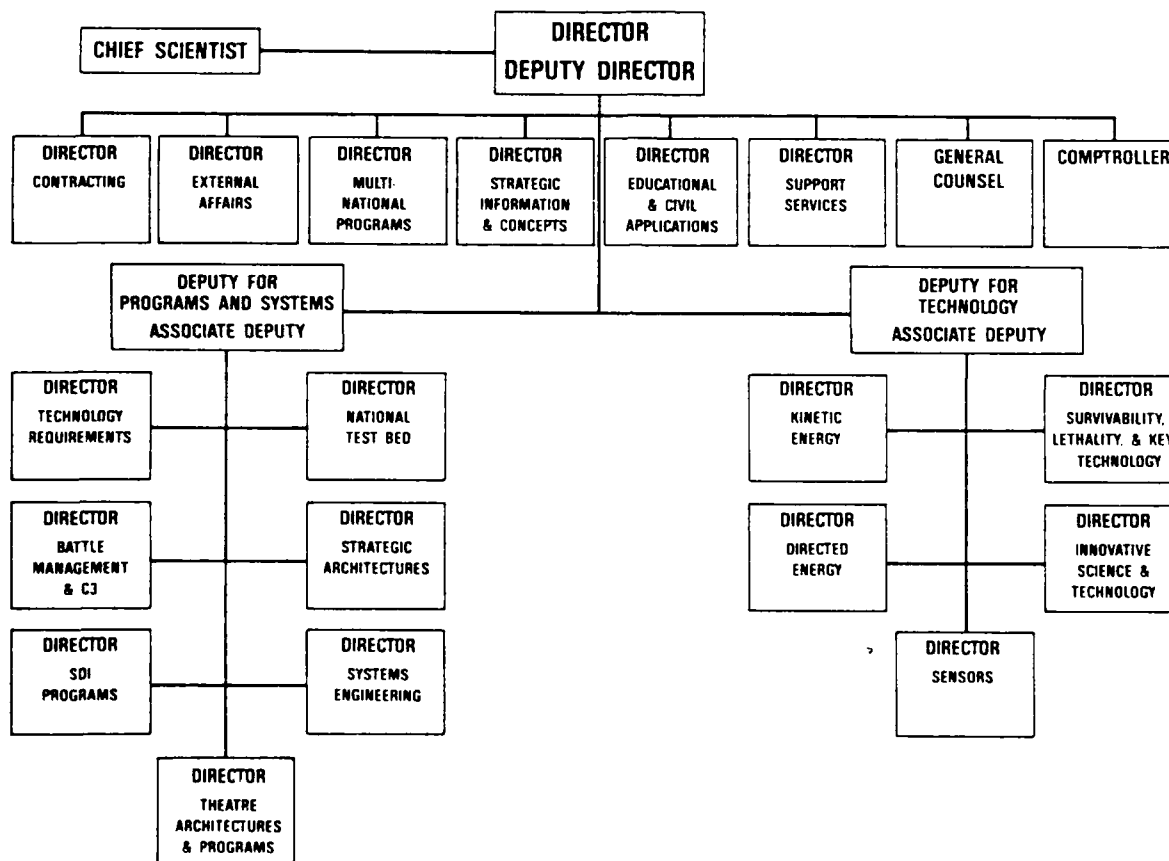


Figure VII.1 Current Organizational Structure of the SDIO

B. SIGNIFICANT ACCOMPLISHMENTS (FY 1986)

Tantamount to successful SDIO program management is effective financial control; this was keynote to the Comptrollership reorganization during FY 1986. As the SDIO and DoD Services and agencies that are engaged in SDIO activities developed their FY 1986 programs and modified existing programs to conform to the SDIO technical objectives and goals, the Comptrollership function concentrated on expanding systems and procedures. These will assist in monitoring and measuring the progress.

Table VII.1 shows that obligation rates for FY 1986 were high and expenditures were comparable to similar DoD research activities. This effort comprised over 1500 contracts; and by 30 September 1986, most of the planned work had been completed. Past Fiscal Year highlights are:

- FY 1986 obligation rates by 30 September 1986 were 97% of funds appropriated and 55% expended.
- SDIO's obligations were higher than other similar research programs for the same period.
- SDIO's expenditure rates were higher than other similar research programs for the same period.
- Over 90% of the planned work was completed by 30 September 1986.

C. CURRENT ACTIVITIES AND FUTURE PLANS

Table VII.2 shows FY 1986 and FY 1987 appropriations, and the budget requests for FY 1988 and FY 1989 by SDIO Program Elements. Items of special interest include the following:

- Over 1500 contracts for technical research in six areas are expected to be executed again in FY 1987.

- Allied governments and their respective business firms continue to indicate support for SDI research and more active participation is expected in FY 1987-1989. The SDIO Comptroller is developing the administration aspects of these efforts to ensure that DoD's financial management channels are responsive.

Table VII.1  
Fiscal Obligation and Expenditure Comparisons Within DoD  
FY 1986

		<u>Obligations (Expressed as %)</u>						
		<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>
Total Army R&D	\$ 4.6B	48	57	63	70	74	78	91
Total Navy R&D	\$ 9.6B	74	78	84	86	90	92	95
Total AF R&D	\$13.0B	48	55	59	64	71	79	88
SDIO	\$ 2.7B	58	68	75	82	86	90	97
DARPA	\$ 0.7B	43	57	57	71	71	71	86
AF Strat R&D	\$ 5.1B	49	53	57	61	61	76	82

		<u>Expenditures (Expressed as %)</u>						
		<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>
Total Army R&D	\$ 4.6B	15	20	24	26	35	39	46
Total Navy R&D	\$ 9.6B	15	20	26	32	43	45	58
Total AF R&D	\$ 13.0B	18	24	28	32	38	44	50
SDIO	\$ 2.7B	8	17	20	31	38	43	55
DARPA	\$ 0.7B	6	14	14	29	43	43	51
AF Strat R&D	\$ 5.1B	18	24	27	31	33	39	45

Table VII.2  
SDIO Appropriations and Funding Requests  
FY 1986-1989  
(In Millions of Dollars)

	<u>FY 1986</u>	<u>FY 1987</u>	<u>FY 1988</u>	<u>FY 1989</u>
RDT&E				
SATKA	\$844.756	\$910.963	\$1492.680	\$1859.530
DEW	795.819	843.600	1103.680	1245.820
KEW	595.802	729.600	1074.730	1199.650
SYSTEMS	211.648	386.900	627.340	787.510
SLKT	214.002	338.037	900.363	1162.189
MGMT HQ	<u>13.122</u>	<u>19.900</u>	<u>22.000</u>	<u>27.330</u>
TOTAL RDT&E	\$2675.149	\$3229.000	\$5220.793	\$6282.029

FY 1987 SUPPLEMENT                    (\$500.837)

PROGRAM	
SATKA	\$70.000
DEW	70.000
KEW	60.000
SYSTEMS	40.000
SLKT	<u>260.000</u>
PROGRAM TOTAL	(\$500.000)
PAY-SATKA	(0.837)

FY 1987 REPROGRAMMING (SATKA)    13.600

MILCON	<u>3.080</u>	<u>10.300</u>	<u>125.195</u>	<u>18.000</u>
TOTAL	\$2678.229	\$3753.737	\$5345.988	\$6300.029

In Figure VII.2, a trend line entitled Noncancelable Commitments (NCC) continues to be included among the more traditional financial indicators of obligations and expenditures to show planned performance for FY 1987. The NCC is designed to indicate actual government liability regardless of obligations and expenditures. It has become an SDIO management tool to measure actual work accomplished by the activities using SDIO resources. The NCC is closely related to cost accounting procedures used in the profit-oriented private sector to measure results, including:

- Assets acquired;
- Work performed;
- Real-time debts;
- Materials, deliveries, etc.; and
- Liabilities for goods and services received.

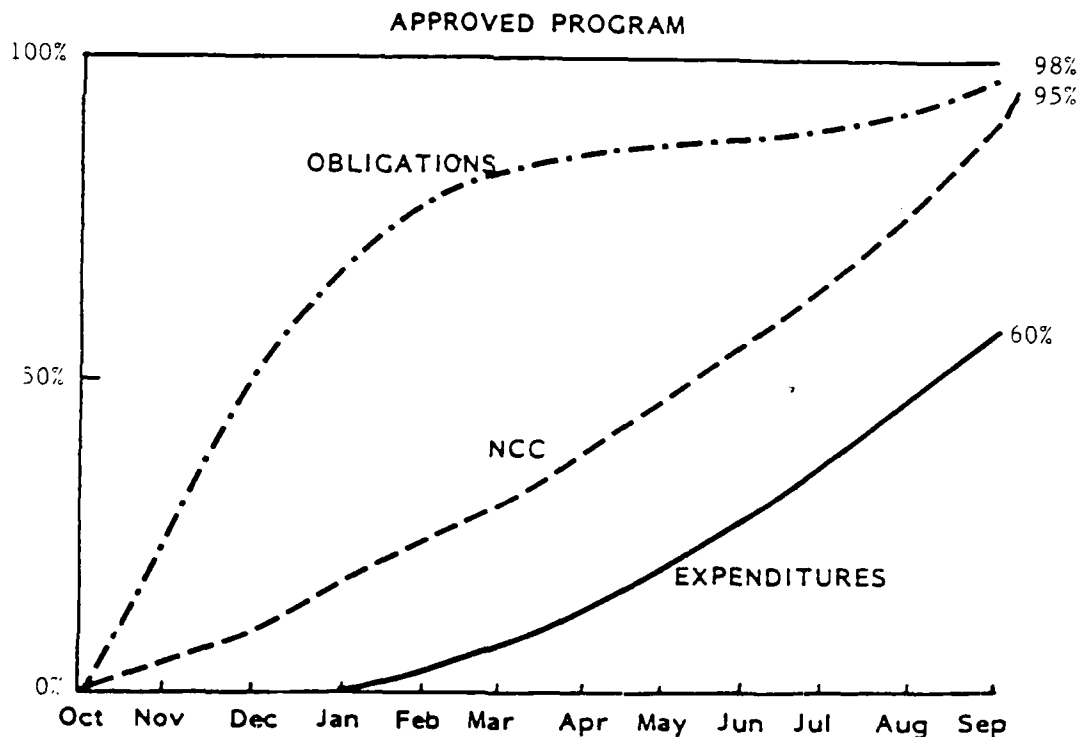


Figure VII.2 SDIO Projections for FY 1987

CHAPTER VIII  
CIVIL APPLICATIONS FOR PROMISING SDI TECHNOLOGIES

A. BACKGROUND INFORMATION

Historically, both DoD and NASA have significantly advanced the state-of-the-art and spurred the American economy by transferring technology to and from military and space programs. Through the various military Service research and development agencies, NASA centers, and federal laboratories, significant advances in technology and recent inventions have been made transferable to the private sector in many forms that are common-use items of today and new products of tomorrow.

In light of this, the SDIO Office of Civil Applications (CA) has been established to help make SDI technology available to other DoD and federal agencies as well as business and research interests in the American private sector. Specifically, reapplication of the technology generated by the SDI promises a broad range of "spin-offs" that can add up to significant benefits in terms of human welfare, industrial efficiency, and economic value through tomorrow's practical application.

The SDIO Civil Applications program will be conducted consistent with U.S. government laws, regulations, and policy on information security, the protection of military and space critical technology, and proprietary rights. A referral data base will be developed containing synoptic data regarding new and unique SDI-generated technologies and will be accessible via computer modem to qualified American business and academic clients who have been approved under procedures established by DoD Directive 5230.25. The data base will also be open to all federal and state agencies. Consistent with the multinational nature of the SDI research effort, the SDIO will respond to specific requests from allied firms and research institutions

for unclassified information regarding individual technologies in accordance with the Memorandums of Understanding and Data Exchange Agreements signed between the Department of Defense and allied signatories.

The SDIO Civil Applications program activities will reach across the broad technical community of government, industry, and academia to employ volunteer scientific and industrial advisers who will assist in identifying and promoting technology applications. A Civil Applications Committee will be established as a subcommittee of the SDIO Advisory Committee consisting of senior government, civil, and industry leaders supported by recognized experts in specific technical fields. Technology Applications Panels will function on a continuing basis to assist in reformatting technology into industrial technology profiles, identifying potential applications, reviewing client inquiries, and recommending avenues for further development or research.

Technology Applications Panels are being established in the following generic technology areas:

- Biomedical applications;
- Electronics, communications, and computer applications;
- Power-generation, storage, and transmission applications; and
- Materials and industrial process applications.

B. MEDICAL FREE ELECTRON LASER PROGRAM

In 1984, the Congress recognized the potential uses of free electron laser technology for medical research and included this effort within the SDI budget. Subsequently, the Congress broadened the scope of the Medical Free Electron Laser (MFEL) program to include medical, biomedical, and materials research.

In accordance with the intent of Congress, five regional MFEL centers are being established at: (1) Stanford University, CA; (2) University of California at Santa Barbara; (3) Brookhaven National Laboratory, NY; (4) National Bureau of Standards, MD; and (5) Vanderbilt University, TN.

The MFEL program draws upon the resources and expertise of 18 universities, two national laboratories, two commercial laboratories, and one hospital to explore the following areas:

- Preclinical medical research: Surgical applications, therapy, and the diagnosis of disease, are being pursued at the Massachusetts General Hospital, the University of Utah, Northwestern University, Baylor Medical School, and the University of California at Irvine.
- Biophysics research: is being conducted at the University of Michigan; Purdue; Princeton; the University of Texas; Jackson Laboratories, ME; and Physical Science, Inc., MA.
- Materials science: is being investigated at Brown University, State University of New York at Buffalo, University of Utah, and Stanford, Vanderbilt, Princeton, and Southern Methodist universities.

The program is projected at a funding level of \$15 million per year with all associated hardware to be in place by FY 1989.

#### C. POTENTIAL SDI SPIN-OFFS

The economic implication for the SDI Program to provide a substantial return on investment is obvious. Some key examples of SDI technology that have potential civil applications are:

- Computer data processing speed and efficiency enhancements through improved components, circuitry, and software;
- Electronic components which are lighter, smaller, more capable and energy efficient;
- Software with artificial intelligence that would allow computer systems to learn from experience and make realistic deductions;
- Optical computing using laser light instead of electrical circuits for data transmission and other optical applications;
- Electrical power systems which are more efficient and less expensive;
- Sensors which are lighter, smaller, more sensitive and less expensive for medical applications, manufacturing, research, control systems, and a host of other applications;
- Cryogenic cooling systems which are lighter, smaller, more efficient for use in food preservation, medical applications, etc.
- Lightweight mirrors with computer-controlled adaptive alignment for laser applications to manufacturing processes;
- Electrical systems hardening techniques applicable to reducing or eliminating noise and other interference in communications systems;

- Tracking and pointing technology developed for surveillance may be valuable in applications to commercial aircraft guidance and control and ground traffic monitoring;
- Tomography-associated technology may enhance medical techniques for location and discrimination of soft tissue abnormalities;
- Free electron laser applications to noninvasive cancer surgery, early diagnosis and treatment of heart disease and stroke, and other medical diagnostic and treatment applications; and
- Integration of laser technology, robotics, and computerized precision control techniques into applications associated with a host of manufacturing processes, and biomedical applications.

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**APPENDIX A**

**KEY FUNCTIONS OF A DEFENSE  
AGAINST BALLISTIC MISSILES**

APPENDIX A  
KEY FUNCTIONS OF A DEFENSE AGAINST BALLISTIC MISSILES

OVERVIEW OF THE DEFENSE ENVIRONMENT

The critical requirement for an effective ballistic missile defense system is the need to achieve low leakage of nuclear warheads when threatened by both large, sophisticated attacks as well as attacks on the defense system itself. A strategic defense capable of engaging appropriate targets along the ballistic missile flight path must perform certain key functions:

- Detection: The rapid and reliable attack warning and readying of defense assets for target intercept. This includes providing full-time surveillance of ballistic missile launch areas (potentially worldwide) to detect an attack and identify its location; characterizing the composition and intensity of the attack; determining probable targeted areas for confident battle initiation; and providing track data to assist in target acquisition.
- Tracking, Identification/Discrimination: The precise and enduring "birth-to-death" tracking of targets and other objects of interest associated with a ballistic missile attack. This includes the effective discrimination of penetration aids and decoys; timely kill assessment; and efficient battle management, data processing, and communications capabilities for battle and defense coordination and optimization.
- Interception and Destruction: The rapid, effective, and discernible kill of ballistic missile boosters, post-boost vehicles, and reentry vehicles along the entire flight path of the ballistic missile. The defense must be capable of stopping an attack ranging

in scope from a single missile to a massive, simultaneous launch that may require 10 or more kills per second by the defensive weapons. Defending against an attack while the ballistic missiles are still at the beginning of their flight paths (the boost and post-boost phases) is attractive, for it maximizes the number of reentry vehicles killed and minimizes the deployment of decoys and penetration aids.

- Battle Management, Coordination: The effective manipulation of information about the defensive battle, the generation of displays to inform the defense commander, and the transmission of his decisions to the defense elements.

There are two basic approaches in designing a system to perform the necessary functions and achieve the goal of very low leakage. The first uses extremely high performance system elements, and the second relies on redundant combinations of system elements performing at more modest levels. It is generally accepted that an efficient defense against a high level of threat is a layered defense requiring all the previously stated capabilities. For example, with a single-layer system, the failure of any function may result in overall failure. The defensive system would only be as strong as its weakest link. A target which is not detected would not be intercepted and thus would leak through the single defensive layer. Similarly, a reentry vehicle that is incorrectly classified as a decoy would not be intercepted. Clearly, very capable system elements would be required for a high confidence single-layer ballistic missile defense.

The second and preferred approach recognizes that near-perfect element performance is unlikely and, even if possible, might be too expensive. This approach envisions a multitiered defense with each tier capable of independently performing the

basic functions of threat detection, tracking, identification, pointing and/or weapon guidance, destruction, kill assessment, coordination, and self-defense. If an element within a single tier fails, the target leaks through to the next tier where the defense has another chance to detect and intercept the target. Three independent tiers, each of which allows 10 percent leakage, for an overall leakage of 0.1 percent, are likely to be less costly than a single tier that has the same total leakage since the performance requirements for each tier can be substantially lower than those required for a stand-alone tier.

The typical trajectory of a current ballistic missile can be divided into four phases:

- A boost phase when the missile's engines are burning and offering intense, highly specific, observables;
- A post-boost phase, also referred to as the bus deployment phase, during which multiple reentry vehicles and penetration aids are being released from a post-boost vehicle;
- A midcourse phase during which RVs and penetration aids travel on ballistic trajectories above the atmosphere; and
- A terminal phase during which RV trajectories and signatures are affected by atmospheric drag.

Shorter-range submarine-launched ballistic missile (SLBM) or intermediate-range ballistic missile (IRBM) trajectories have similar boost and terminal phases but, in most cases, less extensive busing and midcourse phases.

For convenience, the systems functions have been grouped into three categories in the following discussion--surveillance (detection, initial identification), acquisition (tracking, identification/association/discrimination, kill assessment, coordination), and intercept (pointing/guidance, destruction, self-defense).

Boost and Post-Boost Phases. The ability to respond effectively to an unconstrained threat is highly dependent on the capability of a boost-phase intercept system. For every booster with multiple independently targeted reentry vehicle (MIRV) payloads killed, the number of objects to be handled by the remaining elements of a layered defense system can be reduced substantially. Such kills also disrupt the highly structured attacks that stress terminal systems. A boost-phase defense system is currently constrained by extremely short engagement times and a potentially large number of targets. These constraints create a requirement for a surveillance and battle management system with weapons release authority based on predetermined, technically measurable conditions for engagement. They also dictate a weapons system that can deliver enough energy to each target in the limited available engagement time to ensure booster kill.

The post-boost phase is potentially rich in information that can be used for discrimination. In this flight phase the leverage decreases as decoys and RVs are deployed. The post-boost phase offers from 100 to 300 additional seconds for intercept by boost phase weapons and may be the predominant phase accessible after certain Soviet boost-phase responses.

Midcourse Phase. An intercept outside the atmosphere forces the defense to cope with decoys designed to deceive interceptors and exhaust the force. Fortunately, available engagement times are longer (approximately 1500 seconds) than in other phases. This freedom from tight timelines in the

boost (150 to 300 seconds), post-boost (300 to 500 seconds), or terminal (20 to 50 seconds) phases strongly argues that a midcourse intercept system is an important element in a comprehensive defensive capability. The midcourse system must, however, provide both early filtering of nonthreat objects and continuing attrition of threat objects if the defense is to minimize the pressure on the terminal system. Failure to start the defense before midcourse could result in a tenfold to several hundredfold increase in objects in the threat cloud from multiple independently targeted reentry vehicles (MIRVs), decoys, chaff, and space junk.

Terminal Phase. The defended area of a terminal-defense interceptor is determined by its speed and how early it is launched. Since terminal-defense interceptors fly within the atmosphere, their average velocity is limited. How early they can be launched depends on the requirements for discrimination of the target from penetration aids and accompanying junk and designation to the interceptor. A requirement for independent discrimination delays launch of the interceptor and reduces the "footprint" or defended area. Moreover, since the terminal defense of a large area requires many interceptor launch sites, the defense is vulnerable to saturation and preferential offensive tactics. Such structured, preferential attacks suggest complementing the terminal defense with area defenses that intercept at long ranges and provide wider defense footprints. Such a complement is found in a system for exoatmospheric intercepts in the midcourse phase.

The phenomenology and required technology for each phase of a ballistic missile trajectory are different. While there is considerable technical overlap of systems between phases, it is useful to separate system concepts into these phases for the purpose of discussing top-level performance goals, identifying broad technical approaches to achieve those goals, and identifying key issues to be resolved. The remainder of this

appendix discusses these topics in the context of boost, post-boost, midcourse, and terminal defense systems. These discussions establish the basis for the investment strategy and technology development required to realize defense-in-depth concepts.

BOOST PHASE (BOOST IGNITION OF POST-BOOST VEHICLE OPERATIONS)  
Functional Needs

Functional needs and performance goals for defensive actions in boost-phase operations are highly sensitive to assumptions about the number of targets to be engaged as a function of time and/or assumed target vulnerability. The first assumption bounds the performance of the surveillance and target acquisition system, the battle management and data processing system, and the fire-control or weapon-guidance sensors. The second assumption, target vulnerability, has a major impact on the performance of the weapon. Both dictate the number of weapons required. Survival and endurance of all boost-phase systems are crucial.

- Surveillance. The requirement to detect launches and associate target signatures with specific booster tracks is fundamental. High sensor resolution is needed. Upon detection, the system must be capable of handling many individual targets.
- Acquisition. Once the individual booster tracks have been identified, the Battle Management and Command, Control, and Communications (BM/C<sup>3</sup>) systems must allocate individual targets or groups of targets to a specific weapon or weapon platform. A sensor or sensors supporting that platform must then acquire and track the relatively cool booster body in the presence of the hot exhaust plume. The pointing accuracy can vary considerably depending largely on the type of weapon that sensors are supporting.

- Intercept. Directed energy kill mechanisms must, in general, deliver from a few to tens of megajoules of energy to the booster or post-boost vehicle. Some weapons concepts attack targets serially using available battle time to move from target to target. In such systems, retarget time must be limited from a few seconds to a fraction of a second in order to achieve required high kill rates. Other concepts engage targets in parallel and do not require rapid retargeting. Some concepts involve physically hitting the target with a homing warhead that must be precisely guided. Finally, one must sense, in near real-time, whatever characteristic changes indicate that the target has been successfully engaged.

#### Candidate Technologies

Candidate technologies to perform these boost-phase intercept functions are:

- Surveillance. There is sufficient confidence in surveillance technologies that a space-based sensor system can be developed to support boost-phase intercept requirements.
- Intercept. Generic weapons concepts applicable to boost-phase kill include:
  - Thermal kill lasers--burn through of booster skin resulting in breakup of the boosters--include continuous wave (CW) and repetitively pulsed beams over wavelengths from IR to ultra violet (UV).
  - In-depth energy deposition by particle beams--soft kill of electronics, detonation of high

explosives, and melting of components and structures--include neutral and, possibly, charged particles.

- Kinetic energy impact kill using homing projectiles propelled by chemical rockets or an electromagnetic gun.

Since a responsive threat might achieve boost-phase termination in the atmosphere, the need to propagate the kill energy through the atmosphere may limit the applicability of some of the candidates.

#### POST-BOOST PHASE

##### Functional Needs

The post-boost vehicle's dispensing phase begins at the end of booster burn and ends for each reentry vehicle or penetration aid as it leaves the PBV or "bus." Accordingly, acquisition, tracking, and discrimination between RVs and decoys and debris are key functions that begin in this phase and continue into the midcourse phase. Since the target is the PBV, the target engagement and energy delivery functions are similar to those for the boost-phase.

- Surveillance. In the post-boost phase, discriminating RVs from other objects is a key functional need.
- Acquisition. The functional needs are similar to boost-phase needs with some differences.
- Intercept. One would probably use boost-phase kill mechanisms in the PBV phase, although substantial differences in the vulnerability of PBVs and boosters are expected.

### Candidate Technologies

Candidate technologies for performing the post-boost phase functions include:

- Surveillance. Discrimination may be by multispectral sensors of many different wavelengths with a variety of techniques and forming one of a number of platforms.
- Acquisition. The boost-phase candidates are also appropriate candidates for this phase.
- Intercept. The boost-phase candidates are also appropriate candidates for the PBV phase.

### MIDCOURSE PHASE

#### Functional Needs

Midcourse defense involves detecting and destroying RVs after their deployment from the PBV and prior to atmospheric reentry at altitudes of about 100km. Acquisition, tracking, and discrimination are the key functions in continuing defense against ballistic missiles during this phase. Assuming discrimination is possible, multiple engagement opportunities are available over the relatively long flight time.

- Surveillance. An autonomous midcourse surveillance function requires sensors that detect all threatening objects in the midcourse regime, rapidly reject (bulk filter) lightweight decoys and debris that exist in large quantities, precisely track remaining credible objects (RVs and heavy decoys), discriminate the RVs from most of the heavy decoys, provide RV position and trajectory data of adequate accuracy for firing kill devices, and perform kill assessment. As in the PBV phase, groups of objects must be classified, track files established, and state vectors handed over.

- Acquisition. Precision tracking of designated objects is required to provide the position of the target needed for intercept. This consists of trajectory predictions accurate for battle management and hand-over to a midcourse hit-to-kill interceptor. In addition, position accuracy is needed for handover to acquisition, tracking, and pointing subsystems of directed energy weapons.
- Intercept. Since the targets (RVs) must be protected against the heat and forces of reentry, they are inherently hardened to thermal and impulse kill mechanisms. For high confidence, kill mechanisms must deliver a few tens of megajoules of energy to the target. The long duration of the midcourse trajectory offers opportunities for multiple engagements even with modest interceptor velocities.

#### Candidate Technologies

Candidate technologies for performing the midcourse functions include:

- Surveillance. Midcourse surveillance needs may be provided by space-based platforms carrying multiple sensors for multiple functions. These sensor suites would be supported by communications, data processing equipment, and signal processing.
- Acquisition. As in the boost phase, tracking and pointing for designation can be based on technologies now under development.
- Intercept. The long timeline available for midcourse intercept substantially reduces the relative payoff for extremely high velocity delivery of kill energies, and the geometry of the problem provides a wide

variety of locations for basing weapons. Forward basing midcourse interceptors would also provide engagement opportunities just after the reentry vehicles reach apogee. Moreover, space-based kill vehicles would be available globally to defend Europe against intermediate-range missiles. High-performance directed energy weapons may also have potential use during the midcourse phase.

#### TERMINAL PHASE

##### Functional Needs

A terminal defense is sought which protects both urban/industrial and military targets against the residue of an attack that has been engaged in all previous phases of its trajectory.

The driving requirements for the terminal tier of defense are a survivable and affordable system that can defend the entire United States. Defense of soft targets demands a keep-out altitude above which all RVs must be killed to prevent damage to soft targets. The need to provide this keep-out over the entire United States requires that the defense elements have large footprints, that is, the area defended must be large in order to limit the number of elements needed for full coverage.

- Surveillance. The basic functions of the surveillance supporting the terminal-phase system are to acquire and sort all objects that have leaked through early defense layers and to identify the remaining RVs. Such actions will be based, where possible, on hand-overs from the midcourse engagements. Although only a small fraction of the lethal RVs will reach the terminal tier intact, junk from the entire attack may arrive over the United States.

- Acquisition. When a threatening object is identified, a homing interceptor must acquire its target and maneuver to kill it. Homing accuracies depend on the warhead used.
- Intercept. For targets that require the interceptor to fly a considerable distance, the interceptor will take place near the keep-out altitude. The high velocity of the interceptor permits it to have a relatively large footprint.

#### Candidate Technologies

The technology requirements for a terminal defense system which can meet a limited threat are well defined and relatively mature as a result of ongoing research. Both target acquisition and tracking interceptor/kill vehicle requirements have been analyzed extensively. The candidate technologies emerging from such studies are:

- Surveillance. A well-defined concept uses an airborne optical sensor that would detect arriving reentry bodies and initiate tracking on those above an established threshold. The platform can carry enough sensors to redundantly detect and track all credible objects.

#### SPECIAL CONSIDERATIONS--SHORTER-RANGE BALLISTIC MISSILES

Slower reentry speeds, greater angle of reentry, less MIRVing, and fewer penetration aids, plus potentially low apogees of depressed trajectory SLBMs and IRBMs, pose a different set of defense problems. These factors could provide offsetting advantages in defending against shorter-range systems. The low apogees associated with some of the shorter-range classes of IRBMs or with depressed SLBMs make midcourse intercept difficult. However, the limited geographical area threatened by IRBMs would enhance the effectiveness of the terminal-defense layer.

Defense against tactical ballistic missiles (TBMs) also requires special consideration. However, some of the elements of the terminal tier of a defense system against longer-range missiles could be adapted to antitactical ballistic missile (ATBM) systems.

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***APPENDIX B***

***THE SDI AND THE ALLIES***

## APPENDIX B

### THE SDI AND THE ALLIES

This appendix responds to the Congressional requirement to include in the annual report on Strategic Defense Initiative programs "the status of consultations with other member nations of the North Atlantic Treaty Organization, Japan, and other appropriate allies concerning research being conducted in the Strategic Defense Initiative program."

#### OVERVIEW

When President Reagan first announced the Strategic Defense Initiative in March 1983, he emphasized that the Program would be designed to enhance allied as well as U.S. security. In accordance with that mandate, the SDI is examining technologies and concepts for defense against all ballistic missiles, no matter what their range or armament. The Program strengthens the U.S. commitment to the defense of NATO and other allies and enhances our common security.

The U.S. government has been engaged in close and continuing consultations with its allies on the Strategic Defense Initiative since its inception. The U.S. also conducts ongoing consultations with the allies on exchanges with the U.S.S.R. that bear on the SDI Program at the Defense and Space Talks in Geneva and at other high-level meetings. Those consultations will continue throughout the SDI Program. Furthermore, the U.S. will consult closely with its allies regarding any future decision to develop and deploy defenses against ballistic missiles.

Contacts with the allies on the SDI go well beyond consultation. In March 1985, Defense Secretary Weinberger invited the NATO allies, as well as Australia, Israel, Japan, and South Korea, to participate directly in SDI research. Pursuant to that invitation, Memorandums of Understanding (MOUs) on

participation in SDI research have been signed with the United Kingdom, Federal Republic of Germany, Israel, and Italy, and an increasing number of allied firms and research institutions are performing SDI research.

#### CONSULTATIONS WITH ALLIES ON THE SDI

Consultations with friends and allies on the SDI broadened and deepened throughout 1986. As in past years, such discussions are a regular feature of numerous bilateral and multilateral meetings with allied officials at all levels, both in Washington and abroad. A brief summary of some of the more noteworthy contacts follows.

President Reagan, Secretary of Defense Weinberger, and Secretary of State Shultz have discussed the Program in virtually all their bilateral meetings on security matters with their allied counterparts. Secretaries Weinberger and Shultz also consulted with NATO defense and foreign ministers on the Strategic Defense Initiative and SDI-related arms control issues at the ministerial meetings of the NATO Nuclear Planning Group (March and October 1986), Defense Planning Committee (May and December 1986), and North Atlantic Council (June and December 1986).

In addition, U.S. officials consulted extensively with allied leaders, both bilaterally and at NATO, on the President's October 1986 meeting with General Secretary Gorbachev at Reykjavik and after each round of the Defense and Space Talks in Geneva. Furthermore, government and industry personnel from several allied countries have visited the United States for detailed technical discussions on the SDI Program and tours of SDI research facilities. The SDIO is also sponsoring advanced planning briefings to acquaint government and industry representatives from selected allied nations, as well as U.S. industry, with SDI programs, initiatives, missions, and future acquisition plans.

#### ALLIED PARTICIPATION IN SDI RESEARCH

In March 1985, Secretary Weinberger invited 18 nations to participate in the SDI Program so that the SDI and Western security as a whole could be strengthened by taking advantage of allied excellence in research areas relevant to the SDI. Allied participation in SDI research--brought about through technical merit and rigorous competition--is of great benefit to the United States as well as to the participating nations. It allows the U.S. to accomplish SDI objectives as quickly as possible with work of the highest quality at the lowest possible cost.

The United States has signed MOUs on participation in SDI research with the United Kingdom (December 1985), Federal Republic of Germany (March 1986), Israel (May 1986), and Italy (September 1986). Discussions are now under way with Japan regarding Japanese participation in SDI research. The MOUs are designed to facilitate allied participation in SDI research insofar as that is permitted under U.S. laws, regulations, and international obligations (including the ABM Treaty).

All SDI contracts are awarded strictly on the basis of technical merit and cost, in accordance with the competitive procurement practices mandated by the Congress. The Bayh Amendment to the Fiscal Year 1973 Department of Defense Appropriations Act provides that no DoD research and development contracts may be awarded to foreign firms if a U.S. entity is equally competent to carry out the work and is willing to do so at lower cost. The Defense Appropriations Act for Fiscal Year 1987, as in Fiscal Year 1986, prohibits any set-aside of funds for SDI research contracts to foreign firms and states that U.S. firms should receive SDI contracts unless such awards would be likely to degrade research results.

In addition to these rules, laws and policies governing rights to research results developed under U.S. contracts

ensure that the U.S. technology base receives the benefits of all SDI research, whether performed by a domestic or foreign contractor. In conformance with these laws and policies, the U.S. government will receive rights to use the technology developed under SDI contracts. Contractor rights to use the results of their SDI research depend on security considerations and the specific conditions of each contract. These ground rules for cooperation are fully reflected in each of the MOUs the U.S. has signed on participation in SDI research.

Following is a summary of major SDI contracts and subcontracts awarded to allied firms and research establishments as of December 1986:

- United Kingdom: \$28.9 million. Work on optical and electron computing, ion sources for particle beams, electromagnetic rail gun technology, optical logic arrays, meteorological environment, and theater defense architectures.
- Federal Republic of Germany: \$48.2 million. Work on tracking and pointing, optics, free electron laser technology, and theater defense architectures.
- Israel: \$10.8 million. Work on electrical and chemical propulsion, short-wave chemical lasers, and theater defense architectures.
- Italy: \$2.3 million. Work on cryogenic induction, millimeter-wave radar seekers, and theater defense architectures.
- France: \$3.4 million. Work on free electron laser technology, sensors, and theater defense architectures.

- Belgium: \$90,000. Work on theater defense architectures.
- Netherlands: \$40,000. Work on theater defense architectures.

#### DEFENSE AGAINST SHORTER-RANGE BALLISTIC MISSILES

The U.S. and NATO, as well as Israel, are considering the need for antitactical ballistic missile defenses in light of the increasing tactical missile threat they confront. NATO and Israel are engaged in a number of studies to determine what measures should be taken to meet that threat while the U.S. Army continues to address the issue through its Antitactical Missile (ATM) Program. At the same time, the Strategic Defense Initiative continues to examine technologies and concepts for defenses against ballistic missiles of all ranges and armaments, including those shorter-range systems which directly threaten our friends and allies. The Army's Strategic Defense Command has been designated as the SDI executive agent for managing the tactical missile defense portion of the SDI Program. Technology advances achieved in the SDI Program will be made available to the Army's ATM program through the Strategic Defense Command.

Allied and U.S. Army ATM efforts are separate from, but closely coordinated with, the SDI research program. The U.S. expects that technologies and concepts being examined under the SDI can make a substantial contribution to NATO and other allies' efforts to strengthen defenses against tactical missiles. Similarly, it is anticipated that many results of SDI research will substantially contribute to the effort to improve conventional forces in general.

SDI research awards for regional (theater) defense architecture studies have been granted over the past year to the governments of the United Kingdom and Israel and to seven

multinational contractor teams. Those architecture studies, from a range of expert sources, will provide a better understanding of the requirements for a credible, robust defense. The awards to the seven multinational contractor teams are for the first phase of theater ballistic missile defense architecture studies. The contracting teams will complete in July 1987 the first phase of work and then compete for longer-term second-phase contracts to develop detailed system requirements and specifications for potential theater defenses against ballistic missiles. The teams are headed by Messerschmitt-Boelkow-Blohm (West Germany); CoSyDe, a consortium formed by Aerospatiale and Thomson-CSF (France); SNIA-BPD (Italy); LTV Corporation, RCA Corporation, Hughes Aircraft Company, and Lockheed Corporation (United States). Together these seven teams comprise 51 companies, including one Israeli and 29 European firms.

The multinational nature of this effort reflects the long and fruitful tradition of close cooperation among allied and other friendly governments and firms and expresses the depth of the United States' commitment to the common defense. It will ensure that the best possible work will be done to benefit all parties concerned. The theater architecture studies being pursued under the SDI will contribute importantly to our collective thinking on the vital issue of ensuring NATO's and other allies' security against the threat of Soviet shorter-range missiles over the near and longer term.

***APPENDIX C***

***POSSIBLE SOVIET RESPONSES TO THE SDI***

APPENDIX C  
POSSIBLE SOVIET RESPONSES TO THE SDI

INTRODUCTION AND SCOPE

The following section addresses:

- A survey of ongoing Soviet strategic defense programs which began before March 1983, and
- Potential Soviet responses to SDI.

Since the SDIO is addressing a number of system architectures and technologies, the range of potential responses is broad. Different threat options are continuously being evaluated within the SDI technology program to measure the military effectiveness, survivability, and cost-effectiveness of strategic defense architectures, systems, and components.

SOVIET TRENDS

The Soviet emphasis on strategic defense is firmly grounded in Soviet military doctrine and strategy, which call for the following actions in the event of nuclear war:

- Destruction and disruption of the West's nuclear-associated command, control, and communications;
- Destruction or neutralization of as many of the West's nuclear weapons as possible, both on the ground and at sea, before they could be launched;
- Interception and destruction of surviving weapons--aircraft and missiles--before they reach their targets; and
- Protection of the Party, the State, military forces, industry, and the essential working population

against those weapons that survived attacks by Soviet offensive and active defensive forces.

The U.S.S.R. stresses effective strategic defenses in addition to offensive forces. In the Soviet view, the U.S.S.R. can best achieve its aims by political means short of war. These aims are backed by Soviet military power which they perceive to be capable of defeating any enemy who dares counter Soviet ground strategy by military means. Moscow's doctrine requires a war-fighting capability which, if needed, can carry out a first strike to destroy much of the U.S. and allied capacity for retaliation.

In Military Strategy, the basic Soviet strategic treatise, originally published in 1962, Marshal V.D. Sokolovskiy, defined the aim of Soviet strategic defenses in this way: "They have the task of creating an invincible system for the defense of the entire country.... While, in the last war, it was sufficient to destroy 15-20 percent of the attacking air operation, now it is necessary to assure, essentially, 100 percent destruction of all attacking airplanes and missiles."

Soviet offensive and defensive force developments over the past 25 years demonstrate that the strategy described by Sokolovskiy still applies. The Soviet emphasis on research into defenses against ballistic missiles was articulated by then Minister of Defense Grechko shortly after the signing of the ABM Treaty in 1972. He told the Soviet Presidium that the Treaty "places no limitations whatsoever on the conducting of research and experimental work directed towards solving the problem of defending the country from nuclear missile strikes."

The Soviets maintain the world's only operational ABM system; it defends Moscow. In 1980, they began to upgrade and expand that system. When completed, the modernized Moscow ABM

system will be a two-layer defense composed of silo-based, modified long-range Galosh interceptors; silo-based, high-acceleration Gazelle interceptors designed to engage targets within the atmosphere; and a new large radar at Pushkino designed to control ABM engagements. The modernized system will have the 100 ABM launchers permitted by the ABM Treaty and could become fully operational by the late 1980s.

The Soviet system for detecting and tracking ballistic missile attacks uses launch-detection satellites, over-the-horizon radars, and a series of large phased-array radars.

The eleven large Hen House ballistic missile early warning radars are at six locations on the periphery of the U.S.S.R. These radars can tell the size of an attack, confirm a warning from the satellite and over-the-horizon radar systems, and provide target-tracking data.

The Soviets are now constructing a network of nine new large phased-array radars that can track more ballistic missiles with greater accuracy than the Hen House network. These radars duplicate or supplement the coverage by the Hen House network, but with greatly enhanced capability. However, one of these radars, under construction near Krasnoyarsk, closes the gap in Soviet radar coverage against ballistic missile attack. Because it is located well within the Soviet border and "looks out" across some 4000 km of Soviet territory, this radar is in direct violation of the ABM Treaty. The Treaty only permits large phased-array radars, for ballistic missile early warning like that at Krasnoyarsk, if they are located on the periphery and oriented outward.

The growing Soviet network of large phased-array radars for ballistic missile detection and tracking, including the one at Krasnoyarsk, is of particular concern when linked with other Soviet ABM efforts. Such radars might allow the Soviet

Union to move rapidly to construct a nationwide ABM defense. The Soviets are developing ABM components which apparently are designed to allow them to construct ABM sites in a matter of months instead of years. By using these components, the Soviets could undertake rapid ABM deployments to strengthen the defenses of Moscow and defend key targets in the western U.S.S.R. and east of the Urals.

The Soviets have probably also violated the ABM Treaty prohibition on testing surface-to-air missile (SAM) components in an ABM mode. The SA-10 offers several significant advantages over older strategic SAM systems, including a capability against tactical ballistic missiles. The SA-X-12B GIANT is capable of doing the same. Additionally, both of these systems may have the potential to intercept some types of strategic ballistic missiles.

The Soviets continue to field the world's only operational ASAT system. It is launched into an orbit similar to that of the target satellite and, when it gets close enough, destroys the satellite by exploding a conventional warhead. The Soviet co-orbital antisatellite interceptor is reasonably capable of performing its missions, and thus it is a distinct threat to U.S. low-altitude satellites.

Other Soviet systems have ASAT capabilities. The nuclear-armed GALOSH ABM interceptor deployed around Moscow has an inherent ASAT capability against low-altitude satellites. The Sary-Shagan lasers may be capable of damaging sensitive components onboard satellites. Although weather and atmospheric beam dispersion may limit the use of ground-based laser ASATs, such systems would quite likely have the major advantage of being able to refire and therefore to disable several targets.

During the next 10 years, the Soviets are likely to retain their current ASAT-capable systems while moving aggressively

ahead in developing and deploying new ASAT systems. Their large-scale ballistic missile defense research and development efforts in laser, particle beam, radio-frequency, and kinetic energy technologies may also soon provide them with significant ASAT capabilities.

The development of a space-based laser ASAT that can disable several satellites is probably a high-priority Soviet objective. The Soviets may deploy space-based lasers for antisatellite purposes in the 1990s, if their technological developments prove successful. Space-based laser ASATs could be launched on demand, or maintained in orbit, or both. By storing a laser ASAT in orbit, the Soviets could reduce the time required to attack a target. This option would decrease the warning time available to the target needed to attempt countermeasures. The Soviets are also developing an airborne laser whose missions could include ASAT, and limited deployment could begin in the early 1990s.

#### EXPECTED SOVIET TECHNOLOGY DEVELOPMENTS

The Soviets are actively engaged in ABM research and development programs. In the late 1960s, the U.S.S.R. initiated a substantial research program into advanced technologies applicable to ballistic missile defense systems. This effort covers many of the same technologies currently being explored for the U.S. SDI but involves a much greater investment of plant space, capital, and manpower. The U.S.S.R. will undoubtedly increase its efforts to acquire Western technologies associated with space and the SDI Program.

#### Laser Weapons

The U.S.S.R.'s laser program is considerably larger than U.S. efforts and involves over 10,000 scientists and engineers as well as more than a half-dozen major research and development facilities and test ranges. Much of this research takes place at the Sary-Shagan Missile Test Center, where ABM

testing also is conducted. At Sary-Shagan alone, the Soviets are estimated to have several lasers for air defense and two lasers probably capable of damaging some components of satellites in orbit, one of which could be used in feasibility testing for ballistic missile defense applications. The Soviet laser weapons program would cost roughly \$1 billion a year in the U.S.

Scientists in the U.S.S.R. have been exploring three types of lasers that may prove useful for weapons applications-- the gas-dynamic, the electric discharge, and the chemical. They have achieved impressive output power levels with these lasers. The Soviets are possibly exploring the potential of visible and very-short-wavelength lasers. They are investigating the excimer, free-electron, and X-ray lasers, and they have been developing argon-ion lasers.

The Soviets appear generally capable of supplying the prime power, energy storage, and auxiliary components for their laser and other directed energy weapons programs. They have probably been developing optical systems necessary for laser weapons to track and attack their targets. They produced a 1.2-meter segmented mirror for an astrophysical telescope in 1978 and claimed that this reflector was a prototype for a 25-meter mirror. A large mirror is considered necessary for a long-range space-based laser weapon system.

The U.S.S.R. has progressed in some cases beyond technology research. It has ground-based lasers that have some capability to attack U.S. satellites and could have a prototype space-based antisatellite laser weapon by the end of the decade. Additionally, the Soviets could have prototypes for ground-based lasers for defense against ballistic missiles by the late 1980s and could begin testing components for a large-scale deployment system in the early 1990s.

The remaining difficulties in fielding an operational laser system will require more development time. An operational ground-based laser for defense against ballistic missiles probably could not be deployed until the late 1990s or after the year 2000. If technological developments prove successful, the Soviets might be able to deploy a space-based laser system for defense against ballistic missiles after the year 2000. The Soviets' efforts to develop high-energy air defense laser weapons are likely to lead to ground-based deployments in the early 1990s and to naval deployments in the mid-1990s.

#### Particle Beam Weapons

Since the late 1960s, the Soviets have been exploring the feasibility of using particle beams for a space-based weapon system. They may be able to test a prototype space-based particle beam weapon intended to disrupt the electronics of satellites in the 1990s. An operational system designed to destroy satellites could follow later, and application of a particle beam weapon capable of destroying missile boosters or warheads would require several additional years of research and development.

Soviet efforts in particle beams, particularly ion sources and radio-frequency accelerators for particle beams, are impressive. In fact, much of the U.S. understanding of how particle beams could be made into practical weapons is based on published Soviet research conducted in the late 1960s and early 1970s.

#### Radio Frequency Weapons

The U.S.S.R. has conducted research in the use of strong radio frequency (high-power microwave) signals that have the potential to interfere with or destroy critical electronic components of ballistic missile warheads or satellites. The Soviets could test a ground-based radio frequency weapon capable of damaging satellites in the 1990s.

### Kinetic Energy Weapons

The Soviets also have research programs underway on kinetic energy weapons, which use the high-speed collision of a small object with the target as the kill mechanism. In the 1960s, the U.S.S.R. developed an experimental "gun" that could shoot streams of particles of a heavy metal, such as tungsten or molybdenum, at speeds of nearly 25 kilometers per second in air and more than 60 kilometers per second in a vacuum.

Long-range, space-based kinetic energy weapons for defense against ballistic missiles probably could not be developed until at least the mid-1990s. However, the Soviets could deploy in the near term a short-range, space-based system for space station defense or for close-in attack by a maneuvering satellite. Current Soviet guidance and control systems are probably adequate for effective kinetic energy weapons use against some objects in space, such as satellites.

### Computer and Sensor Technology

Advanced technology weapons programs--including potential advanced defenses against ballistic missiles and ASATs--are dependent on remote sensor and computer technologies, areas in which the West currently leads the Soviet Union. The Soviets are devoting considerable resources to acquiring Western know-how and to improving their abilities and expertise in these technologies. An important part of that effort involves the increasing exploitation of open and clandestine access to Western technology. For example, the Soviets operate a well-funded program through third parties for the illegal purchase of U.S. high-technology computers, test and calibration equipment, and sensors.

### COUNTERMEASURES ANALYSIS

This section responds to the Congressional request to include in the Report to Congress on the SDI a section on Countermeasures. The purpose of the SDIO Countermeasures

Program is to provide, in conjunction with the Intelligence Community, technical evaluations of potential countermeasures and to ensure that countermeasures are taken into account by SDI system designers and technology developers. In addition, the Countermeasures Program is also charged with designing realistic targets for use in SDI test programs.

During the past year, four technical Red-Blue Team analyses were conducted to assist in improving the understanding of countermeasures by both SDI system concept and technology developers. The High Endoatmospheric Defense System (HEDS) analysis addressed the terminal defense region. The Ground-Based Midcourse Interceptor (GBMI) analysis addressed the midcourse region, and the Space-Based Interceptor (SBI) analysis addressed the boost and post-boost phases of the overall strategic defense engagement. The Architecture Red-Blue analysis is considering the entire engagement region and will review the results of the other Red-Blue analyses and examine how an offensive force planner might attempt to balance countermeasures over the entire engagement.

The Ground-Based Midcourse Interceptor and Space-Based Interceptor Red-Blue interactions were initiated to examine midcourse and boost/post-boost defenses. One Red-Blue exchange has been conducted in support of each analysis.

Both the GBMI and SBI analyses are in their early stages. Other possible defense systems countermeasures and time periods must be examined before major conclusions are drawn.

The Architecture Red-Blue analysis has only proceeded through the first half of its initial interaction. The Red Team has postulated several countermeasures which may be effective against several defense layers. The Blue Team is now studying these countermeasures and assessing their effectiveness. It is too early in the process to draw conclusions.

The SDIO process has resulted in an improved understanding of countermeasures and countermeasure responses. New ideas for countermeasures and countermeasure responses were identified, evaluated, and are being considered in both technology and system design.

Significant results from initial analyses have been identified, and requirements have been developed for additional analysis by the Red and Blue Teams. Round I efforts have resulted in defense system designs that are more robust to possible Soviet countermeasures, and it is expected that the second round of analyses will produce additional significant modifications to the defense system designs.

**APPENDIX D**

**COMPLIANCE OF THE STRATEGIC DEFENSE INITIATIVE  
WITH THE ABM TREATY**

APPENDIX D  
COMPLIANCE OF THE STRATEGIC DEFENSE INITIATIVE  
WITH THE ABM TREATY

INTRODUCTION AND SCOPE

This appendix addresses compliance with the ABM Treaty of activities under the Strategic Defense Initiative (SDI) and related programs. The treatment of devices based on "other physical principles" is discussed. The existing process for ensuring compliance with Strategic Arms Limitation (SAL) Agreements, including organizational responsibilities and reporting procedures and their application to SDI and the ABM Treaty, is also described.

POLICY

There are four major points to be made regarding United States policy on compliance with the ABM Treaty.

First, the SDI research program is being conducted in a manner fully consistent with all U.S. treaty obligations. The President has directed that the Program be formulated in a fully compliant manner, and the DoD has planned and reviewed the program (and will continue to do so) to ensure that it remains compliant.

Second, the President directed that as a matter of policy the SDI Program be conducted according to a more restrictive interpretation of the ABM Treaty than the United States could justifiably observe. Under the broader interpretation of the Treaty, ABM systems that are "based on other physical principles" (i.e., other than ABM interceptor missiles, ABM launchers, and ABM radars) and including components capable of substituting for ABM interceptor missiles, ABM launchers, or ABM radars may be developed and tested but not deployed, regardless of their basing mode. Under the more restrictive interpretation, development and testing of ABM systems based

on other physical principles are allowed only for fixed land-based systems and components.

Since the President has decided as a matter of policy to observe the more restrictive interpretation of the ABM Treaty, all statements in this appendix regarding compliance with treaty provisions should be understood to be based on the more restrictive interpretation. The President has reserved the right to restructure the SDI Program to take full advantage of the broader bounds of the ABM Treaty.

Third, because there are areas which are not fully defined in the ABM Treaty\*, it is necessary in some cases to infer specific standards for compliance. Three of the more important working principles of this review used to establish such standards are that:

- Compliance must be based on objective assessments of capabilities which support a single standard for both sides and not on subjective judgments as to intent which could lead to a double standard of compliance.
- The ABM Treaty in Article V prohibits the development, testing, and deployment of ABM systems and components that are sea-based, space-based, air-based, or mobile land-based. However, the Treaty does not limit

\*An example of such an area within the restrictive interpretation of the Treaty is the subject of components. ABM components are defined in the Treaty as "currently" (i.e., 1972) consisting of ABM missiles, launchers, and radars. But there is no agreed definition of what constitutes an "ABM component" based on other physical principles, beyond the guidance in Agreed Statement D: "In order to ensure fulfillment of the obligation not to deploy ABM systems and their components except as provided in Article III of the Treaty, the Parties agree that in the event ABM systems based on other physical principles and including components capable of substituting for ABM interceptor missiles, ABM launchers, or ABM radars are created in the future [i.e., after 1972], specific limitations on such systems and their components would be subject to discussion in accordance with Article XIII and agreement in accordance with Article XIV of the Treaty."

research and its associated testing short of field testing of a prototype ABM system or component.

- The ABM Treaty, of course, restricts only defenses against strategic ballistic missiles; it does not apply to defenses against cruise missiles or defenses against nonstrategic ballistic missiles, provided that such defenses do not have an ABM capability.

Fourth, the United States government must guard against permitting a double standard of compliance, under which the Soviet government could expect to violate particular provisions of arms agreements without consequence, while the U.S. continues to comply with all provisions. We have not considered Soviet violation of the ABM Treaty in this report. The United States has reserved the right to respond to that violation in appropriate ways, some of which may eventually bear on the Treaty constraints as they apply to the United States.

#### OVERALL COMPLIANCE ASSESSMENT

The entire SDI Program is being conducted in compliance with the ABM Treaty and all other U.S. treaty obligations. The SDI Program consists of near-term technology research projects and major experiments. The research projects directly support the major experiments by providing the necessary technologies. These activities are well defined and clearly compliant. The major experiments, most of which are to be conducted in later years, are also being planned to be fully compliant. Experiments can demonstrate technical feasibility without involving ABM systems or components or devices with their capabilities. Thus, useful and compliant experiments, in both "mobile" and "fixed land-based" configurations, are allowed.

#### EXISTING COMPLIANCE PROCESS FOR SDI

DoD has in place an effective compliance process (established in 1972 after the signing of the SALT I agreements),

under which key offices in DoD are responsible for overseeing and will continue to oversee SDI compliance with all U.S. arms control commitments. Under this process the SDI Organization (SDIO) and Services ensure that the implementing program offices adhere to DoD Compliance Directives and seek guidance from offices charged with oversight responsibility.

Specific responsibilities are assigned by DoD Directive 5100.70, 9 January 1973, Implementation of SAL Agreements. The Under Secretary of Defense for Acquisition, USD(A), ensures that all DoD programs are in compliance with U.S. strategic arms control obligations. The Service Secretaries, Chairman of the Joint Chiefs of Staff, and Agency Directors ensure the internal compliance of their respective organizations. The DoD General Counsel provides advice and assistance with respect to the implementation of the compliance process and interpretation of arms control agreements.

DoD Instruction S-5100.72 establishes general instructions, guidelines, and procedures for ensuring the continued compliance of all DoD programs with existing arms control agreements. Under these procedures questions of interpretation of specific agreements are to be referred to the USD(A) to be resolved on a case-by-case basis. No project or program which reasonably raises an issue as to compliance can enter into the testing, prototype construction, or deployment phases without prior clearance from the USD(A). If such a compliance issue is in doubt, USD(A) approval shall be sought. In consultation with the DoD General Counsel, OASD/International Security Policy and OJCS, the USD(A) applies the provisions of the agreements, as appropriate. Military departments and DoD agencies, including SDIO, certify internal compliance quarterly and establish internal procedures and offices to monitor and ensure internal compliance.

In 1985, the United States began discussions with allied governments regarding technical cooperation on SDI research.

To date, the U.S. has concluded bilateral SDI Research Memorandums of Understanding with the United Kingdom, Federal Republic of Germany, Israel, and Italy. All such agreements will be implemented in a manner consistent with U.S. international obligations, including the ABM Treaty. The Administration has adopted guidelines to ensure that all exchanges of data and research activities are conducted in full compliance with the ABM Treaty obligations not to transfer to other states ABM systems or components limited by the Treaty, nor to provide technical descriptions or blue prints specially worked out for the construction of such systems or components.

#### CATEGORIES OF TREATY COMPLIANT ACTIVITIES

There are three basic types of SDI activity that are permitted under the compliance policy the United States has adopted with respect to the ABM Treaty. The SDI major experiments described below are grouped according to these categories.

##### Category 1 - Conceptual Design or Laboratory Testing.

This activity precedes field testing and was considered during the ABM Treaty negotiations to be research that was not verifiable by National Technical Means (NTM) and not subject to Treaty limits.

Category 2 - "Field Testing" of Devices That Are Not ABM Components or Prototypes of ABM Components. As noted earlier, Article V prohibits the development, testing, and deployment of ABM systems or components which are sea-based, air-based, space-based, or mobile land-based.

The negotiating record of the ABM Treaty shows it was clearly understood in 1972 that "development" begins when field testing is initiated on a prototype of an ABM component. The definition of "development" applied to the Article V limitations results in the prohibition of field testing of ABM systems or components, or their prototypes, which are other

than fixed land-based. Thus, SDI field tests of space-based or other mobile-based devices cannot involve ABM components or prototypes (or ABM systems or their prototypes). All SDI Category 2 experiments must meet this criterion. For any device to be limited by the ABM Treaty, whether labeled "prototype" or some other term of art, it must constitute an ABM system or component (an ABM interceptor missile, ABM launcher, or ABM radar) or be capable of substituting for such an ABM component.

"ABM systems and components" are defined in Article II as follows:

For the purpose of this treaty an ABM system is a system to counter strategic ballistic missiles or their elements in flight trajectory, currently consisting of (a) ABM interceptor missiles, which are interceptor missiles constructed and deployed for an ABM role, or of a type tested in an ABM mode; (b) ABM launchers, which are launchers constructed and deployed for launching ABM interceptor missiles; and (c) ABM radars, which are radars constructed and deployed for an ABM role, or of a type tested in an ABM mode.

We are applying the rule that all SDI "field tests" not involving fixed, land-based devices must not be conducted in an "ABM mode." The term "tested in an ABM mode" is specifically addressed in a classified Agreed Statement negotiated in 1978 by the U.S. and U.S.S.R. and in the Standing Consultative Commission. That agreement provides, in part, that an interceptor missile is considered to be "tested in an ABM mode" if it has attempted to intercept (successfully or not) a strategic ballistic missile or its elements in flight trajectory. Likewise, a radar is considered to be "tested in an ABM mode" if it performs certain functions such as tracking and guiding an ABM interceptor missile or tracking strategic ballistic missiles or their elements in flight trajectory in conjunction with an ABM radar which is tracking and guiding an ABM interceptor missile. "Strategic ballistic missiles or their elements in flight trajectory" include ballistic target-missiles

with the flight trajectory characteristics of strategic ballistic missiles or their elements over the portions of the flight trajectory involved in testing.

Category 2 experiments must also meet the obligation of Article VI not to give non-ABM launchers, missiles, or radars capabilities to counter strategic ballistic missiles or their elements in flight trajectory and not to test them in an ABM mode.

Allowed Category 2 activities include tests of experimental devices to demonstrate technical feasibility of advanced defenses and gather data prior to construction of a prototype of an actual ABM component. Tests of non-ABM systems performing functions consistent with Treaty obligations (such as air defense and early warning) are also legitimate Category 2 activities.

Category 3 - "Field Testing" of Fixed Land-Based ABM Components. "Field Testing" of fixed land-based ABM components or systems is permitted as long as other Treaty provisions are met. Under Article IV, all such tests must take place at agreed ABM test ranges (for the U.S., White Sands Missile Range and Kwajalein Missile Range), and the total test ABM launcher count must not exceed 15.

Such testing must comply with limitations in Paragraph 2 of Article V on launcher capabilities as follows:

Each party undertakes not to develop, test, or deploy ABM launchers for launching more than one ABM interceptor missile at a time from each launcher, nor to modify deployed launchers to provide them with such a capability, not to develop, test, or deploy automatic or semi-automatic or other similar systems for rapid reload of ABM launchers.

Agreed Statement E prohibits "developing, testing, or deploying ABM interceptor missiles for delivery by each ABM interceptor missile of more than one independently guided warhead."

#### Summary

The SDI projects and experiments have been reviewed to ensure that they will be conducted in accordance with one of the three categories of activities permitted by the Treaty.

The Services and SDIO are obligated to plan and implement these experiments in a compliant manner. Many of the SDI devices do not use traditional technology, but are "based on other physical principles" (such as lasers). In these cases, we have reviewed them by considering their capability to substitute for traditional ABM components, and whether they will be "tested in an ABM mode" by analogy to the 1978 Agreed Statement (which does not address devices based on new technology).

#### COMPLIANCE ASSESSMENT

The entire SDI Program is compliant with the ABM Treaty and all other U.S. treaty obligations. The bulk of the near-term effort consists of technology research projects that support major experiments to be conducted by the SDI Program. Seventeen major experiments and their bases for compliance are summarized below. Three experiments, Space Surveillance and Tracking System (SSTS), Space-Based Hypervelocity Rail Gun (SBHRG), and the High-Brightness Relay (HIBREL) Project, are not considered this year because they are not funded in the requested program. Other experiments have been revised substantially since last year.

ALPHA is a ground-based laser device designed to demonstrate the feasibility of high-power infrared (IR) chemical lasers for space-based applications. The Large Optics Demonstration Experiments (LODE) and Large Advanced Mirror Program (LAMP) are to demonstrate critical beam control and large

lightweight space optics technologies, respectively, in a series of ground-based experiments simulating the space environment. All of these tests are under-roof experiments using devices incapable of achieving ABM performance levels (Category 1).

The SKYLITE program, which consists of the MIRACL laser and the Sea Lite Beam Director subsystems from the former Navy Sea Lite program, will be integrated into an experimental device for ground-based lethality testing against fixed targets at White Sands Missile Range and for high-power propagation tests designed to investigate adaptive correction techniques to compensate for the effects of thermal blooming and atmospheric turbulence. An attempt will be made in a ground experiment to efficiently integrate a laser and beam director which, separated or combined, are not capable of substituting for an ABM component. Neither the power nor the optics are compatible with atmospheric propagation at ranges useful for ABM applications. Experiments are planned against ground-based static targets and airborne instrumented vehicles. The device is not a prototype nor is it ABM capable (Category 2).

The space Tracking and Pointing Experiment (TPE) program will concentrate on a series of experiments with increasing degrees of difficulty, technologies required for tracking and pointing of weapons, and sensors for space- and ground-based applications. Current plans call for a shuttle and free-flyer experiments over the next few years. These devices will also not be capable of achieving ABM performance levels. As these plans become better defined, they will be reviewed to ensure they are in compliance (Categories 1 and 2).

The ground-based Free Electron Laser (FEL) program includes the fabrication at the White Sands Missile Range (WSMR) of an experimental laser to perform an uplink experiment to an instrumented spacecraft which will measure beam properties. Longer-term plans include upgrading this experimental

facility to higher power. Should it achieve ABM capability, the fixed ground-based FEL would be compliant with the ABM Treaty because it will be located at an agreed ABM test range (Categories 2 and 3).

The Neutral Particle Beam Technology Integration Experiment has been significantly reduced in scope due to budgetary limitations. The experiment will be designed to investigate the technologies needed to perform midcourse discrimination or detect nuclear material. This experiment will be conducted in space at low average power using nearby, co-orbital, instrumented targets, and the device will not be capable of autonomously acquiring or tracking ballistic targets. Because of such limitations, this experimental device will not have ABM capabilities. This experiment will not be tested in an ABM mode (Category 2).

The Boost Surveillance and Tracking System (BSTS) experiment is a space-based experiment (which is not yet fully defined) to demonstrate technology capable of upgrading the current space-based early warning system. This experiment will, if successful, also permit a decision to be made on the applicability of more advanced technology for ABM purposes. The experiment will determine if sufficiently sensitive tracking and signature data can be collected on orbit against the earth's background. The BSTS experimental device will not be a prototype of an ABM component and will be limited in capability of performing early warning functions which are permitted by the Treaty. For example, the experimental BSTS will collect ballistic missile plume data, but it will not be capable of real-time data processing for handing off to a boost-phase interceptor. Other capabilities may be limited as well. It will not be tested in an ABM mode (Category 2).

The Airborne Optical Adjunct (AOA) experiment will demonstrate the technical feasibility of long-wavelength infrared

(LWIR) acquisition, tracking, and discrimination of strategic ballistic missiles from an airborne platform to support a ground-based radar. The AOA experimental device will not be capable of substituting for an ABM component due to its platform and sensor limitations. The test platform will be a Boeing 767; the ultimate airborne platform is yet to be determined. The endurance of the test platform is significantly less than that needed for the operational concept. The AOA experiment uses a single, passive sensor. As part of the feasibility demonstration, the AOA experimental device will observe ballistic missile tests flown into the Kwajalein Missile Range (KMR). Any increase in the performance of the AOA experimental device or tests involving ABM interceptor missiles will require prior approval (Category 2).

The purpose of the Space-Based Kinetic-Kill Vehicle (SBKKV) project (which is not fully defined) is to determine the feasibility of target acquisition, tracking, and rocket-propelled projectile launch and guidance. This feasibility may be demonstrated in experiments using space-based or ground-based devices or a combination of both. The demonstration hardware for any space-based experiment will not be an ABM component, will not be capable of substituting for an ABM component, and will not be tested in an ABM mode. There will be no intercepts of strategic ballistic missiles or their elements in flight trajectory in a space-based experiment. Tests involving fixed ground-based ABM interceptors may use ABM components and may be tested in an ABM mode, but will not involve field tests of a prototype of a space-based ABM component. As the plans become better defined, they will be reviewed to ensure compliance (Category 2 or 3).

The ground-based Hypervelocity Rail Gun research program is intended to validate the weapon potential of a hypervelocity gun and associated miniature kill vehicle technology. Several types of projectiles will be fabricated to demonstrate that

precision-guided munitions can be successfully launched from hypervelocity guns. The test devices will not be ABM components and will not have ABM capabilities. They will demonstrate the capability to launch unguided and guided projectiles at hypervelocities from ground-based rail guns within a laboratory environment and will not involve testing in an ABM mode (Category 1).

The SATKA Integrated Experiment (SIE) will investigate technologies in netting together sensors on various platforms to accomplish end-to-end tracking of a strategic ballistic missiles. Passive tracking and handover will be attempted on test vehicles launched from Vandenberg AFB into the Western Test Range. The SIE project will use existing sensors, none of which are ABM components, nor will they be tested in an ABM mode. ABM interceptor missiles will not be involved in any of the experiments (Category 2).

JANUS is a single launch designed to gather signature information. No interception will be attempted with this experiment. This package will have no ABM capability and will not be tested in an ABM mode (Category 2).

The Flexible Lightweight Agile Guided Experiment (FLAGE), formerly called SRHIT, is a research program to explore small nonnuclear, hit-to-kill technology using off-the-shelf components combined with an active radar and small, multiple divert thrusters. FLAGE tests the seeker, guidance, and control technologies for a short-range interceptor at low altitudes. Tests will be conducted at WSMR to complete the FY86 SRHIT test series. Due to its very limited propulsion system, guidance, and radar range, this interceptor is not ABM capable. Additionally, it will not be tested in an ABM mode (Category 2).

The Significant Technical Milestone (STM) II experiment is a research program to characterize and generate a multi-

spectrum sensor data base. A Delta 3910 launch vehicle will be placed in a low earth orbit. The experiment will evaluate state-of-the-art sensors. No interception will be attempted in this experiment. None of the devices used in this experiment are in strategic ballistic missile trajectory. The sensors will not be tested in an ABM mode, and will not be capable of substituting for ABM radars (Category 2).

The High Endoatmospheric Defense Interceptor (HEDI) project is to demonstrate the capability to intercept strategic ballistic missile warheads within the atmosphere. Tests at White Sands Missile Range (WSMR) under the Kinetic Intercept Test Experiment (KITE) program will involve interceptors flown to points in the atmosphere to verify missile integrity, characterize the flight environment, and perform interceptions on targets in trajectories not characteristic of strategic ballistic missile trajectories. The interceptors flown at WSMR will not demonstrate ABM capability, will not have sufficient propulsion to be ABM capable, and will not be tested in an ABM mode. Interceptor flights at Kwajalein Missile Range (KMR) under the HEDI program will involve the allowed tests of nonnuclear ABM interceptor missiles. The interceptors flown at KMR will be ABM capable and will be tested in the ABM mode. All flight tests will be from fixed ground-based launchers without the capability of being rapidly reloaded or launching more than one interceptor missile at a time. The interceptor missiles will not be capable of delivering more than one independently guided warhead (Categories 2 and 3).

The Exoatmospheric Reentry Vehicle (RV) Interceptor System (ERIS) is intended to engage incoming RVs from the time they separate from the post-boost vehicle bus until reentry into the atmosphere. This is an allowed test of a nonnuclear ABM interceptor missile. All interceptor missile flight tests are to be conducted from fixed ground-based launchers at KMR. A series of flight tests is planned. The ERIS interceptor will

be ABM capable and will be tested in the ABM mode. Fixed ground-based launchers will be incapable of launching more than one interceptor missile at a time and will not be rapidly reloadable. The ERIS interceptor missile will not be capable of delivering more than one independently guided warhead (Category 3).

The Terminal Imaging Radar (TIR) will be an X-band ABM radar which will be tested in an ABM mode. Due to funding limitations, this program will incur a one-year delay in its previous schedule. This fixed land-based radar will be tested at an agreed ABM test range (i.e., KMR). The objective is to demonstrate performance and effectiveness of an X-band imaging ABM radar possibly in conjunction with the HEDI experiment at KMR. TIR will be permanently installed in an existing radar building and will require this building for structural support. TIR will perform target precommit discrimination and may hand-over to HEDI (Category 3).

The Long-Wavelength Infrared (LWIR) Probe project (which is not fully defined) will use a ground-launched LWIR sensor in a feasibility demonstration experiment to detect, discriminate, track, and designate midcourse targets. All tests will be conducted from a fixed land-based launcher at an agreed ABM test range. If the LWIR Probe, after it is better defined, is considered an ABM component, it must be fixed, land-based and can be tested only at an agreed ABM test range. Furthermore, it cannot be a prototype of a space-based ABM radar substitute. In the "pop-up" mode from a fixed land-based launcher, the LWIR Probe is not considered air-based or space-based (Category 3).

**APPENDIX E**

**THE NEED FOR A FEDERALLY FUNDED  
RESEARCH AND DEVELOPMENT CENTER (FFRDC)**

APPENDIX E  
THE NEED FOR A FEDERALLY FUNDED RESEARCH AND  
DEVELOPMENT CENTER (FFRDC)

BACKGROUND

The mission of the Strategic Defense Initiative Organization is to objectively assess technical questions relating to strategic defense to provide the President and the Congress with the necessary information to reach a national decision on strategic defense. This includes conducting a long-range, directed research program toward what may be an extremely complex and far-reaching system. The requisite research is correspondingly complex. Programs must be carefully crafted to strike the right balance among pure research, applied experiments, development of research results, and feasibility demonstrations.

The SDIO does no research itself; it is the managing agent for the SDI research program. This by itself is a significant task. A great variety of individual, parallel research efforts must be directed and coordinated to produce integrated results. A common data base must be maintained to avoid unnecessary overlap or duplication of efforts and to facilitate cross-information between research projects. In addition, design development and definition of the system architecture requires ongoing, continuous study, and analysis, including cost, technology, and performance trade-offs among system elements.

The SDIO requires technical support in these areas to properly carry out its SDI program management functions. The accelerating rate of research and the evolution of the Program require that the SDIO focus on actual program management and that the necessary technical support, evaluation, analysis, and integration be provided on a long-term, continuous, conflicts-free basis rather than in a piecemeal, ad hoc manner. There is an immediate need for continuous access to the

highest-quality engineering and scientific talent to provide dedicated support to the SDIO.

The Senate Armed Services Committee Report on the Defense Authorization Act for FY87 confirms the SDIO need for this technical support:

[T]he Committee does recognize the need for such support in carrying out the system trade-offs and system integration efforts required to manage a program as complex as the Strategic Defense Initiative. Therefore, the Committee strongly endorses the establishment of a means to provide technical support, such as was provided to the Air Force's intercontinental ballistic missile (ICBM) development effort by the Aerospace Corporation.

#### ALTERNATIVES AND DOD EVALUATION

On 1 March 1986, the Department of Defense completed an evaluation of the alternatives for satisfying the requirement. The alternatives examined were:

- Government organizations, including expansion of the present SDIO staff; a military Service organization; or a new DoD field agency.
- For-profit firms, including large industrial firms; small- to mid-size System Engineering and Technical Assistance (SETA) contractors; or a new consortium of such firms or contractors, either U.S. or foreign.
- Non-profit firms, including existing Federally Funded Research and Development Centers (FFRDCs); a new division within an existing FFRDC; a new FFRDC; universities; and private not-for-profit laboratories/corporations, new or existing.

The results of the evaluation can be summarized as follows:

- The use of a government organization to provide the special technical support needs of the SDIO was found to be undesirable because: (1) it would be difficult to attract, retain, and manage the required number of highly qualified scientific and engineering personnel, and (2) the needed personnel buildup could not occur or respond in sufficient time to meet changing requirements.
- The use of for-profit firms was found to be undesirable because of the conflicts of interest inherent in the for-profit organization the probable inability to ensure total objectivity and independence of thought, and the negative business impact on such a firm through its necessary dedication to SDIO technical support alone.
- Of the various not-for-profit alternatives examined, a new FFRDC ranked highest. The FFRDC mechanism was considered to offer quick, responsive handling of SDIO needs, while allowing considerable freedom in establishing salary structures and a working environment conducive to attracting the necessary scientific and engineering talent. While an existing FFRDC or other non-profit organization could, potentially, provide capabilities and staff more readily, none have the breadth of specialized expertise to undertake major SDI technology program review and oversight. Any existing organization, including an existing FFRDC or national laboratory will necessarily have ongoing work and a deeper background in one technology or another. In addition, no existing organization is in a position to offer the desired

degree of dedication to and exclusive focus on the SDI Program. Establishing a new FFRDC specifically oriented to SDIO technical support needs was found likely to result in greater responsiveness and support than attempting to reorient an existing FFRDC.

Establishing a new FFRDC, free from commercial ties and dedicated exclusively to the SDI technical functions, is the best alternative to meet that requirement. Accordingly, the Defense Department moved to create a new FFRDC--to be called the Strategic Defense Initiative Institute (SDII)--with funds appropriated for the SDI Program. Originally, the goal for initial operation of the SDII was the end of FY 1986. The SDIO announced its intent to establish a new FFRDC in the Federal Register and the Commerce Business Daily with three sets of announcements over a 90-day period ending June 16, 1986.

#### CONGRESSIONAL ISSUES

As the DoD moved to create the SDII, questions about the decision to establish a new FFRDC surfaced. The SDIO, in response to letters to the SDIO Director, answered questions and addressed issues in several information briefings to professional and personal staff of the Congress, and is providing full disclosure of information when requested about the need for an intended mission of the new FFRDC. (Selected issues will be discussed later in this Appendix.)

Because of these issues, the DoD was cautioned against proceeding further to establish the new FFRDC by the end of 1986. Subsequently, legislation was enacted in the FY 1987 DoD Authorization Act and the Continuing Resolution prohibiting the new FFRDC until authorized with funding appropriated in separate legislation. Further, both the DoD and the Comptroller General were directed to provide detailed reports on the issues.

At the request of certain members of Congress, the Congressional Research Service (CRS) examined the actions to establish the FFRDC and reported (30 May 1986) pros and cons of the initiative. The central conclusion of the CRS report stated:

Given DoD's stated mission (of technology evaluation and system integration), desired organizational characteristics (of being competent, continuous, and conflicts free), and institutional constraints (especially their purposed inability to hire qualified people in-house), the decision to establish a new FFRDC is consistent.

The Comptroller General evaluated (report dated 17 November 1986) the options and plans for SDI technical support. The Comptroller General's findings are entirely supportive of the selection of a new FFRDC to perform the needed technical support, ranking that option as first among eight alternatives in terms of effectiveness. (Tied for effectiveness with establishing a new FFRDC was a new division within an existing FFRDC/national laboratory, although many of the GAO sources offered disadvantages with that alternative.)

In response to draft legislation precluding establishment of the FFRDC until a full DoD report was prepared, a comprehensive report of alternatives was provided to the House and Senate Armed Services Committees on 8 August 1986. A full cost comparison analysis was completed and provided as a supplement to the report to the two Committees on 20 October 1986.

#### RESPONSE TO SELECTED ISSUES

This section discusses issues raised in recent Congressional Committee reports.

(1) Whether or not existing Federally Funded Research and Development Centers, Federal research laboratories, and private contractors would be able to perform the stated objectives of technological integration and evaluation.

This issue was treated exhaustively in the DoD's 1986 study entitled "Assessment of Alternatives." The conclusion of that study, along with the supporting findings of the CRS and the GAO, has been mentioned already in this section. The need for absolute objectivity, conflicts-free advice, and absolute dedication to the SDIO, together with the fact that the vast bulk of SDI-related primary research will continue to be performed by outside entities including consultants and for-profit firms, make it clearly impractical and inadvisable to use an existing organization for this specific purpose.

In addition to these considerations, not one private organization appeared to have the breadth of expertise across all involved technologies to meet the needs of overall technical evaluation and integration for the SDI Program.

Finally, despite numerous inquiries, no private sector firm appeared willing to bid on or operate the FFRDC on the terms deemed necessary--exclusive dedication to the SDIO and no other SDI work--to guarantee the FFRDC objectivity and freedom from actual or apparent conflicts of interest.

It should be stressed that the bulk of primary SDI research will continue to be performed, as now, by other entities, including private consultants and other for-profit firms. We intend strictly to enforce the SDII's focus, on its specific functions.

(2) Whether or not the proposed Federally Funded Research and Development Center will be required and allowed to subcontract research projects to other Federally Funded Research and Development Centers, Federal research laboratories, and private contractors.

It is possible that the SDII may subcontract in appropriate circumstances. However, the SDIO and proposers of the SDII believe that the SDII, over time, will be successful in attracting the necessary personnel to avoid any great frequency of subcontracts.

Furthermore, the SDII should not be awarding any research subcontracts, as the Institute will not be undertaking primary research on major experiments itself, with the possible exception of updating and refining overall system architecture. The primary role of outside entities in performing basic SDI research should remain undisturbed. If a particular issue does require a special panel or outside contractor, the SDII should still possess sufficient expertise and perspective on overall system integration and evaluation to maintain its ability to monitor and review such work. The SDII's intended functions are evaluating and integrating research, not actually doing or contracting the research.

(3) Whether or not the contract to operate the proposed Federally Funded Research and Development Center will be awarded on a competitive basis.

The SDIO is proceeding on other than a formal competitive basis pursuant to its authority under the Competition in Contracting Act (CICA), "to establish or maintain an essential engineering, research, or development capability to be provided by an educational or other non-profit institution or a federally funded research and development center," 10 U.S.C., Sec. 2304(c)(3)(B). The SDIO has determined that, in the particular circumstances of this case, its immediate technical support needs would not be met by a full, formal procurement, which in the case of the most recently established DoD-sponsored FFRDC (the Software Engineering Institute at Carnegie-Mellon University) took almost a year to complete. Rapid progress in research, coupled with intensive Soviet efforts in strategic defense, make providing this additional support to the SDIO time critical.

Accordingly, a number of prominent scientific and technical figures have been invited to submit a proposal to operate the SDII. Many of these persons are also members of the SDI Advisory Committee (SDIAC), a not-for-profit consultative group of private citizens who make available their scientific

and technical expertise to the SDI Program. SDIAC members are probably the most qualified people to establish the SDII: they are intimately familiar with the SDIO's technical support needs and the scope and direction of the Program.

It should also be noted that no commitment has been or will be made until the indicated proposal has been received, reviewed, and evaluated. As noted, the SDIO has been contacted by several companies and individuals in response to the series of announcements of DoD's intent to establish the SDII. However, most callers have indicated their inclination not to proceed when advised of the conflicts-of-interest requirements which dictate that the SDII have no other SDI-related work nor have other clients who themselves have such work. The SDIO has received no proposals, other than the invited proposal, to operate the SDII. It appears, therefore, that there exists only one responsible source for this work within the meaning of Section 2304(c)(1) of the CICA. The SDIO has received one SDII-related proposal to provide interim technical support until the SDII is effectively operational; SDIO has responded that it would consider the proposal should such a need become apparent.

(4) Whether or not all proposals to operate the proposed Federally Funded Research and Development Center will be considered by the appropriate Defense Agency and whether or not such proposals will be subjected to peer review by persons outside the Government.

All proposals to operate the SDII will be considered fully and fairly by the SDIO and the appropriate defense agency. There are no present plans to enlist "peer review by persons outside the government" in this process. The SDIO believes it has the appropriate resources and personnel to best evaluate proposals to operate the SDII. SDIO personnel are most familiar with the status of the SDI research program and the SDIO's particular needs for technical support. The SDIO Deputy Director for Systems and Programs will chair an

evaluation board consisting of SDIO Technology Office Directors. This management team has insights into the needs of the SDI Program to assess any FFRDC management proposals that may be received. If additional outside review is needed, it will be considered at that time.

(5) Whether or not the proposed Federally Funded Research and Development Center will be designed to prevent even the possibility of conflicts of interest by prohibiting any officer, employee, or member of the governing body of the proposed Federally Funded Research and Development Center from holding any position with one of the following:

- (a) The Strategic Defense Initiative Organization.
- (b) The Strategic Defense Advisory Committee.
- (c) Private research centers with a substantial interest in the development of the Strategic Defense Initiative.
- (d) Any other entity with a function or purpose similar to a function or purpose of one of the entities named in subparagraph (a), (b), or (c).

Pursuant to Executive Branch Policy (Office of Federal Policy Letter 84-1), the SDII will be required to operate "free from organizational conflicts of interest." The SDII will not be permitted to have any other SDI-related work beyond its specific technical functions, nor to serve other clients who themselves have SDI or SDI-related work. This is necessary because it is expected that the SDII will provide advice, recommendations, and evaluations to the SDIO that as a practical matter may impact upon the latter's decisions to award federal research and development contracts to other entities (the SDII will have no formal or legal role in such awards, as all management and decision responsibility will continue to be exercised by the SDIO). In addition, in the course of its research and evaluation function, the SDII may undertake research audits of other entities, including other FFRDCs and national laboratories, that are performing research for the SDI Program.

Regarding individual SDII personnel, it is possible that in isolated instances and as a temporary measure, individual technical personnel from the SDIO may be stationed at the SDII to fill an immediate need. There would be no apparent conflicts of interest between the two organizations as the purpose of the SDII is to meet the technical support needs of the SDIO. The SDIO does intend to require that SDII personnel not be permitted during their tenure at the SDII to hold any position with any other organization that has any financial interest in SDI work. The SDIO also expects to incorporate in the sponsoring agreement the appropriate provisions to ensure SDII employees would safeguard information owned by other contractors.

It is possible that some SDII directors may also be SDIAC members. Both positions are uncompensated apart from expenses. However, to avoid any actual or apparent conflicts of interest, it is the intent that such persons will not participate in any evaluation or advice by the SDIAC regarding the SDII. The sponsoring agreement will provide for a 50% maximum limitation on the FFRDC governing body to simultaneously hold positions on the SDIAC.

Regarding post-employment practices, as a nongovernment organization, an FFRDC is not legally subject to the post-employment restrictions that apply for federal employees. Upon additional investigation and inquiry of counsel, the SDIO has been further advised that it would not be appropriate to impose "revolving door" provisions on FFRDC employees.

Concerns in this area appear related to potential involvement of the SDII in review of research proposals. However, SDII functions will be primarily oriented to evaluating research results. When government activities do require the service of a contractor to review proposals submitted by private firms, financial disclosure statements will be obtained

from the reviewing contractor and its agreement to safeguard proprietary information. The SDIO intends to require that this practice be followed by the SDII as well.

(6) Whether or not the sponsoring organization will have any role or influence in the selection of the staff of the proposed Federally Funded Research and Development Center below the head of such center and what that role or influence, if any, will be.

There will be no SDIO participation in search, screening, or selection of SDII management or staff. The sponsoring agreement will require only that the Institute's president and the heads of its several technical directorates be acceptable to the SDIO Director. Specifically, concurrence will be required by the SDIO Director for the top-level executive (e.g., president) of the FFRDC, and coordination with the appropriate peer directors will be required in the selection of the key FFRDC technical personnel. The SDIO will not have veto power over the FFRDC's staff selection except for that of president. The SDIO intends only to seek review and comment authority for other organization officers and senior technical directors of the FFRDC's staff.

Such approval of the handful of key FFRDC personnel is neither new nor unusual. For example, the agreement between the Center for Naval Analysis (CNA) and its sponsoring agency, the U.S. Navy, provides that the Center's president and other top officers, including the directors of its various operating divisions, be subject to approval of Navy representatives. Other FFRDCs also routinely subject their president to the approval of the sponsoring government agency.

The SDIO does not believe such a limited role will in any way adversely impact either the objectivity or the independence of the SDII. The SDIO, as the sponsoring government agency of the SDII, has a duty to ensure fully qualified key personnel for the Institute. To carry out properly its technical support

mission, it is imperative that SDII personnel possess the highest professional qualifications and that there be effective communication and liaison between top management of the two organizations.

There has also been some criticism that the SDII plans to have a "mirror image" structure to the SDIO, and that it should be divided into technical elements (e.g., directed energy, kinetic energy) to correspond to those of the SDIO. This is only a suggestion. Since the SDII is an independent entity, it can determine its own structure. This clearly makes sense, given the close working relationship and the need for effective liaison between the two organizations.

(7) Whether or not a prescribed minimum percentage of the annual budget of the proposed Federally Funded Research and Development Center will be set aside and devoted exclusively to independent research to be conducted without regard to the preferences or desires of the sponsoring organization.

The SDIO agrees that the ability to initiate related research and studies is valuable and should be explored. While the SDIO cannot commit in advance to any fixed portion of its budget being devoted to independent studies, it agrees that some flexibility should be built into the Institute, and the SDIO will explore contract provisions in negotiation toward that end.

The new FFRDC will primarily be a systems engineering/system integration (SE/SI) organization as opposed to one devoted to studies and analyses. However, studies and analyses are an essential part of SE/SI activity and therefore are not mutually exclusive. When analyses are conducted as a part of the technological or development planning of the organization, it becomes an appropriate activity for the SDII to perform. Analyses and studies are necessary in the early stages of the SDI Program.

### POLICY ROLE

The SDII will be a purely technical support group. The SDIO will retain all management and decision responsibility for the SDI Program. The SDII is being established for a very specific purpose--to provide scientific and technical support to the SDIO for evaluating and integrating research. The SDII is not to perform any oversight or policy functions. Those functions, in whole or part, are the role of other organizations, including the Congress. As described in OFPP Policy Letter 84-1, supra, the purpose of an FFRDC is to provide support to its sponsoring agency. Neither the SDII, nor the SDIO itself, will be making national policy decisions on strategic defense. Their mission is to provide objective technical and feasibility data.

To meet these technical support needs and provide the SDIO with objective, conflicts-free advice, the SDIO judged it best to opt for a new organization exclusively dedicated to these narrow functions. No particular bias or point of view is being sought. Obviously, there must be a commitment to exploring fully and fairly the possibility and technical feasibility of strategic defense. That is the purpose of the SDI Program, and given Soviet efforts in this area and the right of any government to protect its people, it would be imprudent not to do so. There is no intent to assure a predetermined view. As noted in the CRS report, supra, "it is not DoD's intention to establish any organization that is unsympathetic to the vision behind SDI; rather it is DoD's intention to establish an organization that is unbiased in its evaluation of which technologies and system concepts are best suited to meet SDI objectives" (p. 22, emphasis in original).

The SDII will be independent in the sense that it will be self-managed and will provide objective, conflicts-free support, recommendations, and evaluations to the SDIO. It is not intended to be "independent" in the sense of having its own

agenda or policy role, nor would that be proper. Though there will be close liaison between the two organizations, there is no reason to believe that such a working relationship will lead reputable scientists to compromise objectivity or independence.

The requirements that the SDII submit work plans every 6 months and that its work proposals be subject to SDIO approval are reasonable to ensure that the new center fulfills its stated purpose, meets the SDIO's technical needs, and maintains a proper focus on its specific functions without encroaching the private sector or other organizations. The SDIO is not averse to contract provisions that permit the SDII flexibility to initiate its proposals, but it is not reasonable to commit a fixed percentage of its budget to such ends, particularly in light of the history of severe cutbacks in requested SDI funding.

#### COST COMPARISON

##### Approach

To gain insight on the costs associated with a new federally funded research and development center, a cost comparison has been made of the actual costs associated with existing FFRDCs versus those of a for-profit SE/SI firm versus those of a DoD laboratory. In conjunction with this analysis, an estimate of the costs associated with establishing a new FFRDC for the SDIO will be discussed.

Comparisons are based upon the cost per MTS, or member of the technical staff. The acronym MTS is a historical designation for select technical professionals who provide the scientific and engineering expertise required in Scientific and Engineering support contracts, including FFRDCs. Although the term has never been equivalent in meaning between any two contracts, an MTS has been described as a professional scientist or engineer actively and directly engaged in performing

the development planning, system engineering, research and experimentation, and technical support. MTS is the basic unit of measurement for stating technical manpower requirements. The mix of education levels, years of experience, functional specialties, and even the number of hours per year that constitute one MTS may differ from place to place.

#### Source

Air Force Headquarters prepared a report entitled "Acquisition Management Review of Scientific and Technical Support Contracts," dated 1 August 1986. The cost data used in this appendix on FFRDC and SE/SI contracts and establishing a new FFRDC are from this Air Force report as is the approach used in developing the cost data for the DoD laboratory.

Cost per MTS includes total contract costs divided by the number of MTSSs. The composition of costs that comprise MTS total costs include: direct labor, travel, computer costs, consultants, facilities, outside procurement, overhead and fringes, other direct costs, and profits/fees. The Air Force made rough adjustments in the raw cost data to eliminate major anomalies in cost per MTS and normalize the manner in which given MTSSs per year were calculated among contractors. Similar adjustments were made to the raw cost data for the DoD laboratory.

#### Alternatives

The following is a comparison of the adjusted cost per MTS for existing FFRDCs, a for-profit SE/SI firm, and a DoD laboratory using 1985 data; an explanation for the differences in cost per MTS of these alternatives; and a brief explanation of how each of these costs were developed:

1. Cost per MTS of Alternatives (1985 dollars)

- FFRDC

Range: \$134,000 - \$180,000

Average: \$148,000

- SE/SI Firm (for-profit)

Actual: \$156,747

- DoD Laboratory (to represent the costs of an in-house SDIO adjunct)

Actual: \$143,340

2. Differences in Cost per MTS of Alternatives

There are several explanations for the differences in cost per MTS of these alternatives, particularly the FFRDCs and the SE/SI (for-profit) firms. SE/SI firms receive higher fees averaging 10 to 11% whereas FFRDCs receive on the average 0 to 4%. For FFRDCs, the government does not pay for depreciation on real property, thus the only source of money to these contractors for purchase of such assets is through profit retention or from other sources such as endowment funds. SE/SI firms, however, charge the government for depreciation on real property. To obtain government business, SE/SI firms additionally charge the government substantial bid and proposal costs, not incurred or passed on to the government by FFRDCs.

3. Development of Cost per MTS for Alternatives

FFRDCs. The 1985 figure from the Air Force report represents an average of five FFRDCs reviewed. The range of adjusted costs per MTS for the FFRDCs reviewed is \$134,000 to \$180,000. Those FFRDCs at the higher end of the scale include laboratories, organizations with a substantial proportion of PhDs included in the MTS, and organizations with larger support-employee to MTS-employee ratios.

SE/SI Firm (for-profit). The 1985 figure was developed by averaging the cost per MTS of two SE/SI for-profit contractors included in the Air Force report. The firms were chosen because they represent the kind of SE/SI support the SDIO's FFRDC would provide.

DoD Laboratory (to represent the costs of an in-house SDIO adjunct). The 1985 figure represents data gathered on the Naval Surface Weapons Center (NSWC), an industrially funded activity which provides technical support for the Navy and other defense activities that need technical products and services for ship combat systems, ordnance naval mines, and strategic systems. NSWC represents an in-house resource with significant MTS talent and a cost accounting system similar to that of a private firm. The figure represents what it might cost the SDIO for an adjunct from government resources to fulfill the mission of an FFRDC. Adjustments were made similar to those made by the Air Force to reflect an MTS composition approximating that of an FFRDC or SE/SI firm.

#### Estimate for New FFRDC

In the analysis of costs for existing alternatives, an average cost per MTS of \$148,000 was derived for existing FFRDCs, with a range of cost per MTS of \$134,000 to \$180,000. Since the SDIO's FFRDC should have a large proportion of PhDs included in the MTS and a large support-employee to MTS-employee ratio, it is reasonable to conclude that the cost per MTS would be at the higher end of the scale. An estimate of \$164,000 is midway between the average cost per MTS and the highest cost and represents a reasonable estimate of the cost per MTS for the SDIO's FFRDC in 1985 dollars.

The \$164,000 figure does not consider startup costs. Startup costs are inherent when establishing any new organization, be it a new FFRDC, private firm, or federal research laboratory. These costs are difficult to estimate since they

involve a number of variables including recruiting and hiring talented people and locating and obtaining facilities as well as the necessary equipment. Normally these startup costs dissipate over time. Included in the Air Force's review of FFRDCs was a newly established FFRDC whose cost per MTS was projected to stabilize after two years. Using this data and projecting for SDIO's FFRDC, the cost per MTS for SDIO's FFRDC would stabilize at \$164,000 (in 1985 dollars) in the third year.

#### Summary

The data below make the following cost comparison for the various alternatives relative to establishing a new FFRDC for the SDIO:

<u>Existing FFRDC</u>	<u>SE/SI Firm</u>	<u>In-house Adjunct</u>	<u>New FFRDC</u>
\$134,000-\$180,000	\$156,747	\$145,340	\$164,000

Although establishing a new FFRDC represents one of the highest cost alternatives, the benefits of a new FFRDC dedicated to the SDIO far outweigh any differences in cost.

***APPENDIX F***

***FUNDING REQUESTS FOR SDI PROGRAM ELEMENTS***

Program Element: #63223C

Mission Area: #555 - Strategic Defense Initiative

Title: Systems Analysis & Battle Management

Budget Activity: #2 - Advanced Technology Development

FY 1988 / FY 1989 RDT&E DESCRIPTIVE SUMMARY

RESOURCES (PROJECT LISTING) : (\$ IN THOUSANDS)

Project Number	Title	FY1986 Actual	FY1987 Appropriation	FY1988 Estimate	FY1989 Estimate	ADDITIONAL TO COMPLETION	TOTAL ESTIMATED COST
TOTAL FOR PROGRAM ELEMENT		212,348	386,915	627,340	787,510	Continuing	Continuing
01	SDI Strategic Architecture	63,524	58,430	91,024	77,960	Continuing	Continuing
02	SDI Systems Engineering*	12,093	20,223	38,992	53,624	Continuing	Continuing
03	Theater Architecture*	1,700	39,797	38,440	37,883	Continuing	Continuing
04	BM/C3 Technology	70,900	88,500	121,843	134,136	Continuing	Continuing
05	BM/C3 Experimental Systems	23,435	80,730	172,874	203,533	Continuing	Continuing
06	National Test Bed	11,993	60,620	119,163	228,378	Continuing	Continuing
70	Countermeasures*	6,065	5,000	0***	0***		
81	Innovative Science & Technology**	13,392	18,115	28,004	34,996	Continuing	Continuing
84	Civil Applications**	0	2,000	2,000	2,000	Continuing	Continuing
86	Medical Free Electron Laser**	9,248	13,500	15,000	15,000		

\* In the FY 1987 Descriptive Summaries the efforts for these projects were contained in Project 1.

\*\* In the FY 1987 Descriptive Summaries these projects were not shown but were considered as overall program cost and were spread across all program elements.

\*\*\* In FY 1988 this effort has been consolidated within Program Element 63224C.

Program Element: #63220C

Mission Area: #555 - Strategic Defense Initiative

Title: Surveillance, Acquisition, Tracking, and Kill Assessment  
Budget Activity: #2 - Advanced Technology Development

FY 1988 / FY 1989 RDT&E DESCRIPTIVE SUMMARY

RESOURCES (PROJECT LISTING) (\$ IN THOUSANDS)

Project Number	Title	FY1986 Actual	FY1987 Appropriation	FY1988 Estimate	FY1989 Estimate	ADDITIONAL TO COMPLETION	TOTAL ESTIMATED COST
TOTAL FOR PROGRAM ELEMENT							
01	Radar Discrim & Data Collect	21,024	12,723	22,601	34,675	Continuing	Continuing
02	Optical Discrim & Data Collect	117,734	90,648	87,903	80,079	Continuing	Continuing
03	Imaging Radar Technology	30,450	26,186	31,957	38,103	Continuing	Continuing
04	Laser Radar Technology	75,436	96,374	148,319	177,585	Continuing	Continuing
05	IR Sensor Technology	82,150	78,668	93,706	98,761	Continuing	Continuing
06	Boost Surveillance & Tracking Sys	81,135	130,090	256,107	344,748	Continuing	Continuing
07	Space Surveillance & Tracking Sys	48,961	47,604	191,800	242,172	Continuing	Continuing
08	Airborne Optical Surveillance Sys	134,937	99,502	103,950	140,680	Continuing	Continuing
09	Terminal Imaging Radar Demo	31,761	26,294	117,038	136,351	Continuing	Continuing
10	Interactive Discrimination	7,569	4,506	32,170	61,683	Continuing	Continuing
11	Signal Processing Technology	94,748	105,917	134,588	145,092	Continuing	Continuing
12	SATKA Integration & Support	95,018	149,551	248,040	311,200	Continuing	Continuing
13	Countermeasures	650	800	0	0	Continuing	Continuing
14	Innovative Science & Technology	25,383	42,100	24,500	48,401	Continuing	Continuing
15	Shuttle Recovery	0	13,600	0	0	0	0

Program Element: #63221C  
Mission Area: #555 - Strategic Defense Initiative

Title: Directed Energy Weapons  
Budget Activity: #2 - Advanced Technology Development

FY 1988 / FY 1989 RDI&E DESCRIPTIVE SUMMARY

RESOURCES (PROJECT LISTING) : (\$ IN THOUSANDS)

Project Number	Title	FY1986 Actual	FY1987 Appropriation	FY1988 Estimate	FY1989 Estimate	ADDITIONAL TO COMPLETION	TOTAL ESTIMATED COST
TOTAL FOR PROGRAM ELEMENT							
01	Tech Base Development	803,401	843,600	1,103,680	1,245,820	Continuing	Continuing
02	Technology Integration Experiments	437,400	339,650	340,499	408,563	Continuing	Continuing
03	Concept Formulation & Technical Development Planning	309,500	402,050	587,880	646,105	Continuing	Continuing
		24,000	26,800	32,300	28,000	Continuing	Continuing
04	Technology Support Programs	32,501	62,400	115,000	128,160	Continuing	Continuing
05	Innovative Science and Technology		12,700	28,001	34,992	Continuing	Continuing

Program Element: #63222C

Mission Area: #555 - Strategic Defense Initiative

Title: Kinetic Energy Weapons  
Budget Activity: #2 - Advanced Technology Development

FY 1988 / FY 1989 BDT&E DESCRIPTIVE SUMMARY

RESOURCES (PROJECT LISTING) (\$ IN THOUSANDS)

Project Number	Title	FY1986 Actual	FY1987 Appropriation	FY1988 Estimate	FY1989 Estimate	ADDITIONAL TO COMPLETION	TOTAL ESTIMATED COST
TOTAL FOR PROGRAM ELEMENT							
01	Space - Based Kinetic Kill Vehicle (KKV) Systems	134,385	126,791	303,503	357,429	Continuing	Continuing
02	Exo Atmospheric KKV Systems	61,599	107,600	220,550	307,649	Continuing	Continuing
03	Endo Atmospheric KKV Systems	76,689	111,310	237,580	238,817	Continuing	Continuing
04	Mini - Projectiles	55,953	74,456	102,947	134,668	Continuing	Continuing
05	Test & Evaluation	185,898	252,099	109,258	46,917	Continuing	Continuing
06	Allied / Theater Defense	69,881	44,344	72,896	79,173	Continuing	Continuing
07	Innovative Science and Technology	11,397	13,000	27,996	34,997	Continuing	Continuing

Program Element: #63224C Title: Survivability, Lethality & Key Technologies  
Mission Area: #555 - Strategic Defense Initiative Budget Activity: #2 - Advanced Technology Development

FY 1988 / FY 1989 RDT&E DESCRIPTIVE SUMMARY

RESOURCES (PROJECT LISTING) : (\$ IN THOUSANDS)

Project Number	Title	FY1986 Actual	FY1987 Appropriation	FY1988 Estimate	FY1989 Estimate	ADDITIONAL TO COMPLETION	TOTAL ESTIMATED COST
TOTAL FOR PROGRAM ELEMENT							
01	System Survivability	59,423	59,980	94,198	98,260	Continuing	Continuing
02	Lethality & Target Hardening	78,300	78,032	102,542	98,382	Continuing	Continuing
03	Power & Power Conditioning	49,971	85,682	157,992	186,915	Continuing	Continuing
04	Space Transportation & Support	20,712	36,375	433,798	606,224	Continuing	Continuing
05	Material and Structures	0	14,268	22,512	40,461	Continuing	Continuing
70	Countermeasures	8,678	23,200	42,835	78,400	Continuing	Continuing
81	IS&T	0	18,200	27,992	35,044	Continuing	Continuing
87	HELSTF	0	18,800	18,494	18,503	Continuing	Continuing

Program Element: #65898C Title: Management Headquarters (SDI)  
 DoD Mission Area: 471 - General Management Support Budget Activity: 6 Defense - Wide Mission Support

FY 1988 / FY 1989 RDT&E DESCRIPTIVE SUMMARY

RESOURCES (PROJECT LISTING): (\$ IN THOUSANDS)

Project Number	Title	FY1986 Actual	FY1987 Appropriation	FY1988 Estimate	FY1989 Estimate	ADDITIONAL TO COMPLETION	TOTAL ESTIMATED COST
TOTAL FOR PROGRAM ELEMENT		13,122	19,900	22,000	27,330	Continuing	Continuing
001	Management Headquarters	13,122	19,900	22,000	27,330	Continuing	Continuing
002	Strategic Defense Initiatives Institute (SDII)						